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## ABSTRACT

This curriculum guide contains a course in hydraulics to train entry-level workers for automotive mechanics and other fields that utilize hydraulics. The module contains 14 instructional units that cover the following topics: (1) introduction to hydraulics; (2) fundamentals of hydraulics; (3) reservoirs; (4) lines, fittings, and couplers; (5) seals; (6) fluids and filters; (7) pumps; (8) valves; (9) cylinders; (10) motors; (11) accessories; (12) hydraulic circuits, diagrams, and symbols; (13) general maintenance; and (14) diagnosis and testing. Each instructional unit follows a standard format that includes some or all of these eight basic components: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests. All unit components focus on measurable and observable learning outcomes and are designed for use in more than one lesson or class period. (KC)

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# Hydraulics

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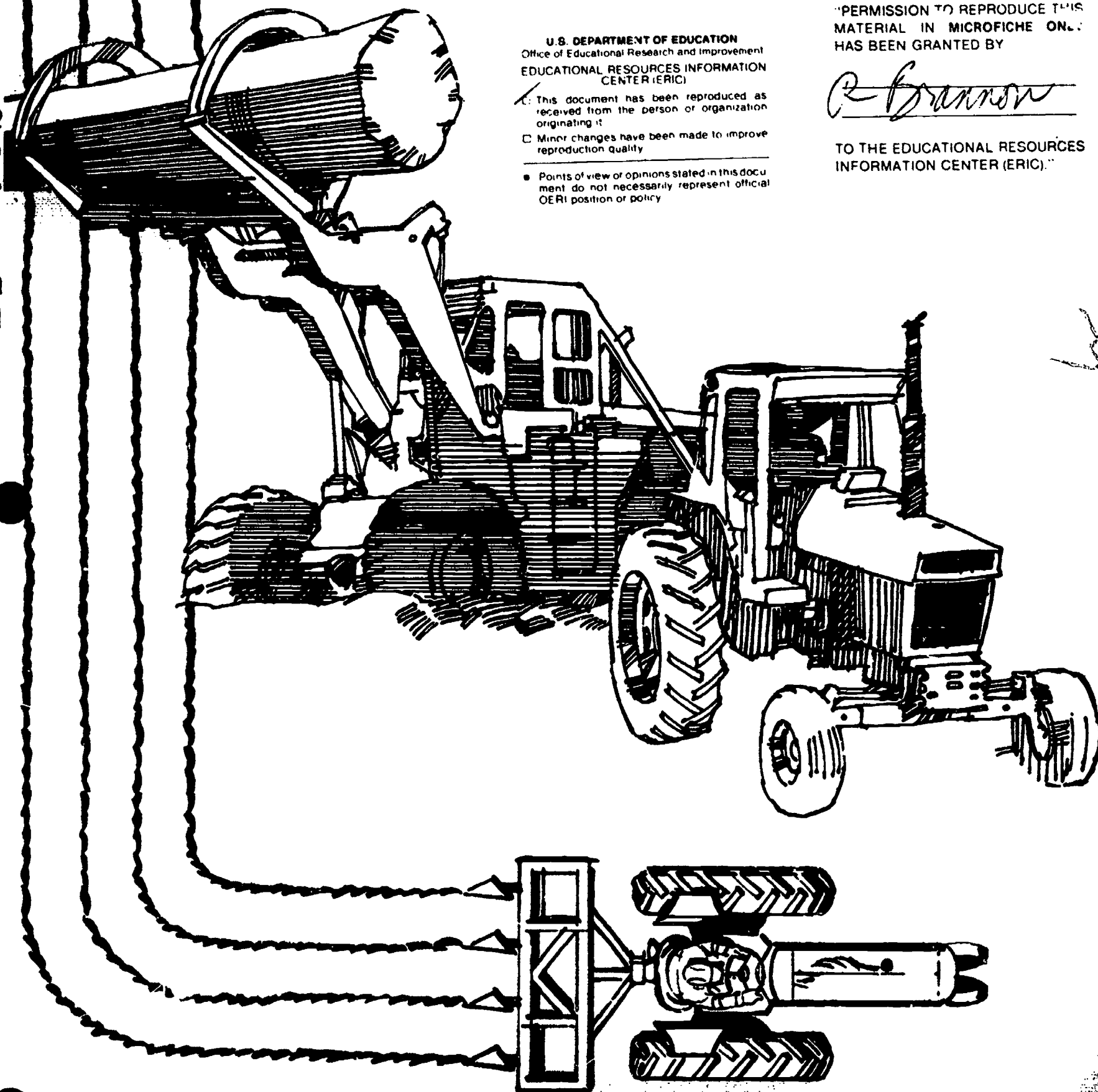
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# HYDRAULICS

Written by  
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Revised by  
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Developed by  
the  
Mid-America Vocational Curriculum Consortium, Inc.

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# HYDRAULICS

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## FOREWORD

Competency-based instructional texts are like most other books in one respect — every now and then they must be revised. Revision is built into the MAVCC development process. After a book is printed and disseminated, a file is maintained of instructor suggestions for changes or additions to the text. In fact, letters and phone calls from instructors who use MAVCC materials are the finest source of guidelines for revision.

Along with items from the suggestion file, MAVCC gathers an *ad hoc* committee to review a given text and make recommendations for revision. The procedure assures that MAVCC books reflect state-of-the-art materials, equipment, and processes.

Instructor suggestions for changes and additions to *Hydraulics* included areas where terminology needed clarification or change. Other suggestions indicated need for minor additions in some of the job sheets. In short, instructors who use *Hydraulics* generally told MAVCC that it was an excellent text just the way it was.

That's why this current revision of *Hydraulics* seems to be very much like the original. According to both instructor and committee input, the book simply didn't need major revisions. That's a credit to Robert Decker, the original author. Yet, there have been significant revisions in objectives related to open and closed-center systems. At numerous points, terminology has been corrected to clarify ambiguous points in the text, and some of the job sheets have been expanded to enhance their instructional value. But even when you count the new illustrations that have been added, you will still feel you're using the original text, and that's a credit to Klane Kirby for his splendid work with the revision.

*Hydraulics* has been on MAVCC's best-seller list since its first publication in 1980. That's a sure sign the book has played a positive role in many vo-tech classrooms. We think the revised edition of *Hydraulics* will keep up the good work. After all, that's what MAVCC's all about.

Les Abel, Chairman  
Board of Directors  
Mid-America Vocational  
Curriculum Consortium

## PREFACE

I can only imagine what the next revision of *Hydraulics* will entail. But whatever it does demand, I know it will all be easier if MAVCC continues to receive input from instructors who use *Hydraulics*.

When you find an error, or a point where an addition is needed to clarify an objective, we'd like to hear from you. It's nice if you have time to write. In fact, many instructors who do write us send copies of the materials with their additions or changes noted at specific points where they should go. We enjoy hearing from instructors who will take that much time, but we enjoy hearing from anyone with a good suggestion and hope that if you don't have time to write, you'll call us toll-free at 1-800-654-3988.

To the best of my knowledge this is the finest introductory hydraulic text that I know about. In fact, it's the only one in a good, solid competency-based format. It has truly earned its place on MAVCC's best-seller list.

Greg Pierce  
Executive Director  
Mid-America Vocational  
Curriculum Consortium



## ACKNOWLEDGEMENTS

Special appreciation is extended to the members of the original Resource Committee who dedicated much time to the identification of tasks and objectives for the text, and for their careful review of the materials after they were written. The Resource Committee includes:

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For editing, thanks to Regina Decker, Kathy Dolan, and Dan Fulkerson.

For a fine job of printing, a final thank you to the printing staff of the Oklahoma State Department of Vocational-Technical Education.

## USE OF THIS PUBLICATION

### Instructional Units

*Hydraulics* includes fourteen units. Each instructional unit includes some or all of the basic components of a unit of instruction: performance objectives, suggested activities for teachers and students, information sheets, assignment sheets, job sheets, visual aids, tests, and answers to the tests. Units are planned for more than one lesson or class period of instruction.

Careful study of each instructional unit by the teacher will help to determine:

- A. The amount of material that can be covered in each class period
- B. The skills which must be demonstrated
  - 1. Supplies needed
  - 2. Equipment needed
  - 3. Amount of practice needed
  - 4. Amount of class time needed for demonstrations
- C. Supplementary materials such as pamphlets or filmstrips that must be ordered
- D. Resource people who must be contacted

### Objectives

Each unit of instruction is based on performance objectives. These objectives state the goals of the course, thus providing a sense of direction and accomplishment for the student.

Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the student performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the intent of the objectives. A limited number of performance terms have been used in the objectives for this curriculum to assist in promoting the effectiveness of the communication among all individuals using the materials.

Reading of the objectives by the student should be followed by a class discussion to answer any questions concerning performance requirements for each instructional unit.

Teachers should feel free to add objectives which will fit the material to the needs of the students and community. When teachers add objectives, they should remember to supply the needed information, assignment and/or job sheets, and criterion tests.

## **Suggested Activities for the Instructor**

Each unit of instruction has a suggested activities sheet outlining steps to follow in accomplishing specific objectives. Duties of instructors will vary according to the particular unit; however, for best use of the material they should include the following: provide students with objective sheet, information sheet, assignment sheets, and job sheets; preview filmstrips, make transparencies, and arrange for resource materials and people; discuss unit and specific objectives and information sheet; give test. Teachers are encouraged to use any additional instructional activities and teaching methods to aid students in accomplishing the objectives.

### **Information Sheets**

Information sheets provide content essential for meeting the cognitive (knowledge) objectives in the unit. The teacher will find that the information sheets serve as an excellent guide for presenting the background knowledge necessary to develop the skill specified in the unit objective.

Students should read the information sheets before the information is discussed in class. Students may take additional notes on the information sheets.

### **Transparency Masters**

Transparency masters provide information in a special way. The students may see as well as hear the material being presented, thus reinforcing the learning process. Transparencies may present new information or they may reinforce information presented in the information sheets. They are particularly effective when identification is necessary.

Transparencies should be made and placed in the notebook where they will be immediately available for use. Transparencies direct the class's attention to the topic of discussion. They should be left on the screen only when topics shown are under discussion.

### **Assignment Sheets**

Assignment sheets give direction to study and furnish practice for paper and pencil activities to develop the knowledge which is a necessary prerequisite to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided which may be used by the student and/or teacher for checking student progress.

### **Job Sheets**

Job sheets are an important segment of each unit. The instructor should be able to demonstrate the skills outlined in the job sheets. Procedures outlined in the job sheets give direction to the skill being taught and allow both student and teacher to check student progress toward the accomplishment of the skill. Job sheets provide a ready outline for students to follow if they have missed a demonstration. Job sheets also furnish potential employers with a picture of the skills being taught and the performances which might reasonably be expected from a person who has had this training.

## **Test and Evaluation**

Paper-pencil and performance tests have been constructed to measure student achievement of each objective listed in the unit of instruction. Individual test items may be pulled out and used as a short test to determine student achievement of a particular objective. This kind of testing may be used as a daily quiz and will help the teacher spot difficulties being encountered by students in their efforts to accomplish the unit objective. Test items for objectives added by the teacher should be constructed and added to the test.

## **Test Answers**

Test answers are provided for each unit. These may be used by the teacher and/or student for checking student achievement of the objectives.

# HYDRAULICS

## INSTRUCTIONAL/TASK ANALYSIS

JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)

RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)

### UNIT I: INTRODUCTION TO HYDRAULICS

1. Definition of hydraulics
2. Systems utilizing hydraulics
3. Advantages and disadvantages of hydraulics
4. Hazards to safety when working with hydraulic systems
5. Safety practices for working on hydraulic systems

### UNIT II: FUNDAMENTALS OF HYDRAULICS

1. Terms and definitions
2. Functions of hydraulic fluids
3. Calculation of pressure
4. Pascal's law
5. Operating principles of a hydraulic press
6. Bernoulli's theorem
7. Components of a basic hydraulic circuit
8. Power transfer in a hydraulic system
9. Components of a hydraulic jack
10. Operation of a hydraulic jack
11. Draw a block diagram of a simple hydraulic system
12. Disassemble, clean and reassemble a hydraulic jack

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

### **UNIT III: RESERVOIRS**

1. Definition of reservoir
  2. Types of reservoirs
  3. Reasons for using a pressurized reservoir
  4. Functions of a reservoir
  5. Parts of a vented reservoir
  6. Parts of a pressurized reservoir
  7. Symbols for reservoirs
- 
8. Clean and inspect a vented reservoir

### **UNIT IV: LINES, FITTINGS, AND COUPLERS**

1. Terms and definitions
  2. Characteristics of steel pipe
  3. Types, construction, and size of steel tubing
  4. Characteristics of hydraulic hose
  5. Types of fittings used with tubing
  6. Types of hose-ends used in hydraulic systems
  7. Types of fittings used in hydraulic systems
  8. Factors to consider when routing tubing in hydraulic systems
  9. Conditions to avoid when routing hydraulic hose
- 
10. Replace a reusable hose end

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

#### **UNIT V: SEALS**

1. Terms and definitions
  2. Types of leakage paths in hydraulic systems
  3. Types of sealing devices used in hydraulic systems
  4. Types of seals and their applications
  5. Types of seal construction
  6. Factors to consider concerning seal material
- 
7. Install an O-ring
  8. Install a seal
  9. Install a packing

#### **UNIT VI: FLUIDS AND FILTERS**

1. Terms and definitions
2. Effects of contaminants in a hydraulic system
3. Practices for assuring hydraulic system cleanliness
4. Functions of a filter in a hydraulic system
5. Surface and depth filters
6. Locations and types of filters in a hydraulic system
7. Types of filter circuits
8. Factors in specifying a filter
9. Symbol for a filter
10. Functions of fluid in hydraulic systems
11. Effect of temperature on the viscosity of hydraulic fluids
12. Common additives in hydraulic systems
13. Safety rules to remember when working with hydraulic fluid

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

**UNIT VII: PUMPS**

1. Terms and definitions
2. Positive and nonpositive displacement pumps
3. Kinds of positive displacement pumps
4. Calculation of pump displacement
5. Calculation of pump flow rate
6. Calculation of pump input and output power
7. Calculation of pump volumetric efficiency
8. Operation of gear pump
9. Operation of vane pumps
10. Axial and radial piston pumps
11. Operation of a radial piston pump
12. Types of axial piston pumps
13. Construction and operation of axial piston pumps
14. Operation of a variable displacement axial piston pump
15. Parts of a servo-controlled variable displacement pump
16. Components and functions of pressure compensated axial piston pumps
17. Causes of cavitation
18. Causes of pump failure
19. Symbols for pumps



**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

20. Disassemble, inspect, and reassemble a gear pump
21. Disassemble, inspect, and reassemble a pressure compensated variable displacement pump

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

**UNIT VIII: VALVES**

1. Terms and definitions
2. Categories of valves
3. Types of pressure control valves
4. Types of pressure relief valves
5. Operation of a pressure reducing valve
6. Types of flow control valves
7. Operation of a needle valve as a flow control device
8. Operation of a high pressure compensated flow control valve
9. Operation of a priority flow divider
10. Operation of a proportional flow divider
11. Types of directional control valves
12. Operation of a check valve and a spool direction control valve
13. Flow paths in a directional control valve
14. Open and closed center systems
15. Types of actuators

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

17. Disassemble, inspect, and reassemble a pressure control valve
18. Disassemble, inspect, and reassemble a flow control valve
19. Disassemble, inspect, and reassemble a directional control valve

16. Symbols for hydraulic valves

**UNIT IX: CYLINDERS**

1. Terms and definitions
2. Operations of a hydraulic cylinder
3. Operations of single and double-acting cylinders
4. Types of double-acting cylinders
5. Parts of a single-acting cylinder
6. Parts of a double-acting cylinder
7. Sources of common failures of hydraulic cylinders
8. Force output of a cylinder
9. Speed of a hydraulic cylinder
10. Power output of a hydraulic cylinder
11. Flow rate required to move a cylinder a given distance in a given time
12. Symbol for a cylinder

13. Disassemble, inspect, and reassemble a hydraulic cylinder
14. Test a cylinder for internal and external leakage

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

#### **UNIT X: MOTORS**

1. Terms and definitions
2. Kinds of hydraulic motors
3. Formula for calculating hydraulic motor load torque
4. Formula for calculating displacement of motor
5. Formula for calculating speed of a motor
6. Formula for calculating inlet pressure
7. Formula for calculating motor input and output
8. Formula for calculating overall motor efficiency
9. Operation of a gear motor
10. Operation of an unbalanced motor vane
11. Types of piston motors
12. Operation of an in-line axial piston motor
13. Disassemble, inspect, and reassemble a gear motor

#### **UNIT XI: ACCESSORIES**

1. Terms associated with accessories
2. Functions of an accumulator
3. Types of accumulators
4. Types of gas-loaded accumulators
5. Safety precautions for working with accumulators
6. Reasons for using a cooler
7. Types of coolers
8. Components of an air-cooled cooler and their functions
9. Common failures of coolers

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

10. Reasons for using a heater
11. Types of heaters
12. Failures of heaters
13. Inspect, clean, and test an air-cooled cooler
14. Inspect, clean, and test a heater

**UNIT XII: HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS**

1. Terms and definitions
2. Components of a basic hydraulic circuit
3. Types of hydraulic circuits
4. Advantages and disadvantages of open-center and closed-center systems
5. Fluid flow in an open-center circuit
6. Fluid flow in multiple actuator open-center systems
7. Valves in neutral and shifted positions in fluid flow
8. Symbols used in a hydraulic schematic
9. Symbols for directional control valves
10. Schematic of open and closed-center systems
11. Draw an open-center hydraulic circuit
12. Show the oil flow in a circuit

**UNIT XIII: GENERAL MAINTENANCE**

1. Reasons for preventive maintenance
2. Factors that can damage hydraulic systems
3. Key maintenance problems

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

6. Perform general maintenance procedures on a hydraulic system
7. Change hydraulic fluid and filter

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

4. Steps for keeping a hydraulic system clean
5. Steps for general maintenance of a hydraulic system

**UNIT XIV: DIAGNOSIS AND TESTING**

1. Terms associated with diagnosis and testing
2. Steps in troubleshooting
3. Types of hydraulic system testers
4. Problems and remedies for an inoperative system
5. Problems and remedies for an erratic system
6. Problems and remedies for a slow system
7. Problems and remedies for a fast system
8. Problems and remedies for a overheated system
9. Problems and remedies for the foaming of fluid
10. Problems and remedies for excessive noise
11. Problems and remedies for a leaking pump
12. Problems and remedies for a load drop
13. Problems causing valves to stick or work hard

**JOB TRAINING: What the  
Worker Should Be Able to Do  
(Psychomotor)**

19. Test a hydraulic pump
20. Locate a problem in a hydraulic system
21. Test a relief valve
22. Test a control valve
23. Test an actuator

**RELATED INFORMATION: What  
the Worker Should Know  
(Cognitive)**

14. Problems causing control valves to leak
15. Problems causing a cylinder to leak
16. Problems in lowering and raising with a control valve
17. Problems and remedies for power steering malfunctions
18. Problems and remedies for brake malfunctions

# HYDRAULICS

## Tools, Equipment, and Materials List

Air-cooled cooler	Lint free rope
Caps to cover fluid ports	Lint free towels
Cylinder	Motor shaft speed measure
Cylinder test fixture	O-ring
Cylinder using wiper seal	O-ring remover tool
Directional control valve	Packings
Double-acting cylinder	Pressure compensated pump
Emery cloth	Pressure control pump
Fitting assembly with O-ring seal	Replacement hose
Flow control valve	Replacement piston seal
Gear motor	Replacement rod seal
Gear pump	Replacement wiper seal
Hand tool set	Safety glasses
Hose with reusable hose ends	Screwdriver
Hydraulic filter	Seal installation tool
Hydraulic fluid	Shipping plugs
Hydraulic jack	Solvent
Hydraulic power supply	Tape measure
Hydraulic system-defective	Vented reservoir
Hydraulic system-open center	Vise
Hydraulic system tester	Wiper seal
Hydraulic system with actuator	Wrenches
Knife	

## ALPHABETICAL LIST OF REFERENCES USED IN DEVELOPING THIS TEXT

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# **INTRODUCTION TO HYDRAULICS**

## **UNIT I**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to discuss advantages and disadvantages of hydraulics, name hazards to safety when working with hydraulic systems, and safety practices when working on hydraulic systems. This knowledge will be evidenced by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Define hydraulics.
2. Select systems which utilize hydraulics.
3. Discuss advantages and disadvantages of hydraulics.
4. Name six hazards to safety when working with hydraulic systems.
5. List five safety practices when working on hydraulic systems.

## INTRODUCTION TO HYDRAULICS UNIT I

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information sheet.
- C. Discuss unit and specific objectives.
- D. Discuss information sheet.
- E. Show examples of different types of systems which utilize hydraulics.
- F. Demonstrate hazards that can occur when working with hydraulic systems.
- G. Demonstrate safety procedures which should be practiced when working with hydraulics.
- H. Contact a local or area Ford tractor dealer and request that the dealer show students the Ford tractors sales video entitled *Tractor Hydraulics, Closed Center Remote Valves*; the production discusses Ford's closed center systems, but the production also deals with open center systems and students should benefit from the effective materials the program contains.
- I. Give test.

### CONTENTS OF THIS UNIT

- A. Objective sheet
- B. Information sheet
- C. Test
- D. Answers to test

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1976.
- B. Pippinger, John J. and Tyler G. Hicks. *Industrial Hydraulics*. Dallas, TX: Gregg Division/McGraw-Hill Book Company, 1979.

# INTRODUCTION TO HYDRAULICS

## UNIT I

### INFORMATION SHEET

I. **Hydraulics** — The study of fluids in motion or at rest

II. **Systems which utilize hydraulics**

(NOTE: There are many systems which utilize hydraulic power. The following are some of the applications on different types of machinery.)

A. **Hitch controls**

1. Three point hitch controls are used for up and down depth control
2. Remote couplers provide outlets for cylinder operation on devices such as log splitters

B. **Backhoe**

(NOTE: A backhoe is a commonly used piece of construction equipment.)

C. **Power steering**

(NOTE: Power steering systems are commonly used on automobiles, trucks, construction equipment, and agricultural equipment.)

D. **Machine tools**

1. Numerically controlled milling machine
2. Industrial robot

E. **Brakes**

(NOTE: Hydraulic brakes can be found on automobiles, trucks, construction equipment, and agricultural tractors.)

F. **Auxiliary controls and actuators**

III. **Advantages and disadvantages of hydraulics**

A. **Advantages**

1. **Flexibility** — Allows a flexible transfer of large forces
2. **Multiplication of force** — Small forces can be used to control large forces

## INFORMATION SHEET

3. Simplicity
  - a. Has fewer moving parts and points of wear than a mechanical system
  - b. Is able to lubricate itself
4. Compactness — Hydraulic motors are more compact than electrical motors of equal horsepower
5. Economy
  - a. Low installation cost
  - b. Low operating cost
6. Safety — Hydraulic systems have fewer moving parts and present fewer potential hazards than mechanical systems with gears and chains

### B. Disadvantages

1. Safety — High pressure is potentially dangerous
2. Cleanliness — System must be kept very clean to prevent excessive wear of the components
3. Leaks — With almost any system under pressure, leaks are inevitable

## IV. Safety hazards when working with hydraulic systems

- A. Components subjected to excessive pressure may explode
- B. Accidental release of trapped oil in hydraulic circuits supporting booms or attachments may cause these components to malfunction or fall suddenly
- C. Hot oil from leaks, disconnected lines, or reservoir drains can cause severe burns
- D. Pin-hole leaks in high pressure circuits can release potentially dangerous fluids
- E. Many hydraulic fluids are extremely flammable
- F. Some hydraulic fluids can irritate or burn when they come in contact with the skin or eyes

## INFORMATION SHEET

### V. Safety practices when working on hydraulic systems

- A. Support booms and attachments before working on a hydraulic system
- B. Operate all control levers to insure hydraulic pressure has been relieved
- C. Loosen lines and components in a circuit slowly to relieve trapped pressure
- D. Stop equipment and repair leaks immediately
- E. Wear safety glasses and a safety helmet as required when working with any system under pressure

# INTRODUCTION TO HYDRAULICS

## UNIT I

NAME \_\_\_\_\_

### TEST

1. Define hydraulics. \_\_\_\_\_  
\_\_\_\_\_
2. Select systems which utilize hydraulics by placing an "X" in the appropriate blanks.
  - \_\_\_\_\_a. Brakes
  - \_\_\_\_\_b. Power steering
  - \_\_\_\_\_c. Hitch control
  - \_\_\_\_\_d. Mechanical differential
  - \_\_\_\_\_e. Machine tools
3. Discuss four advantages and two disadvantages of hydraulics.
  - a. Advantages
    - 1) \_\_\_\_\_
    - 2) \_\_\_\_\_
    - 3) \_\_\_\_\_
    - 4) \_\_\_\_\_
  - b. Disadvantages
    - 1) \_\_\_\_\_
    - 2) \_\_\_\_\_
4. Name six hazards to safety when working with hydraulic systems.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_

**TEST**

- d. \_\_\_\_\_
- e. \_\_\_\_\_
- f. \_\_\_\_\_

5. List five safety practices when working on hydraulic systems.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

# INTRODUCTION TO HYDRAULICS

## UNIT I

### ANSWERS TO TEST

1. The study of fluids in motion or at rest
2. a, b, c, e
3. Discussion should include four of the following advantages and the two disadvantages
  - a. Advantages
    - 1) Flexibility — Allows a flexible transfer of large forces
    - 2) Multiplication of force — Small forces can be used to control large forces
    - 3) Simplicity
      - a) Has fewer moving parts and points of wear than a mechanical system
      - b) Is able to lubricate itself
    - 4) Compactness — Hydraulic motors are more compact than electrical motors of equal horsepower
    - 5) Economy
      - a) Low installation cost
      - b) Low operating cost
    - 6) Safety — Hydraulic systems have fewer moving parts and present fewer potential hazards than mechanical systems with gears and chains
  - b. Disadvantages
    - 1) Safety — High pressure is potentially dangerous
    - 2) Cleanliness — System must be kept very clean to prevent excessive wear of the components
    - 3) Leaks — With almost any system under pressure, leaks are inevitable
4.
  - a. Components subjected to excessive pressure may explode
  - b. Accidental release of trapped oil in hydraulic circuits supporting booms or attachments may cause these components to malfunction or fall suddenly
  - c. Hot oil from leaks, disconnected lines, or reservoir drains can cause severe burns
  - d. Pin-hole leaks in high pressure circuits can release potentially dangerous fluids
  - e. Many hydraulic fluids are extremely flammable
  - f. Some hydraulic fluids can irritate or burn when they come in contact with the skin or eyes
5.
  - a. Support booms and attachments before working on a hydraulic system
  - b. Operate all control levers to insure hydraulic pressure has been relieved
  - c. Loosen lines and components in a circuit slowly to relieve trapped pressure
  - d. Stop equipment and repair leaks immediately
  - e. Wear safety glasses and a safety helmet as required when working with any system under pressure



# **FUNDAMENTALS OF HYDRAULICS**

## **UNIT II**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to discuss the four functions of hydraulic fluids and select true statements concerning the power transfer in a hydraulic system. The student should also be able to identify the components of a basic hydraulic circuit and a hydraulic jack and disassemble, clean, inspect, and reassemble a hydraulic jack. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student will be able to:

1. Match terms associated with fundamentals of hydraulics with their correct definitions.
2. Discuss briefly four functions of hydraulic fluids.
3. Calculate pressure when given force and area.
4. State Pascal's law.
5. Explain the operating principles of a hydraulic press.
6. Discuss Bernoulli's theorem.
7. Identify the components of a basic hydraulic circuit.
8. Select true statements concerning the power transfer in a hydraulic system.
9. Identify the components of a hydraulic jack.
10. Distinguish between the lifting and lowering of a hydraulic jack.
11. Draw a block diagram of a simple hydraulic system.
12. Demonstrate the ability to disassemble, clean, and reassemble a hydraulic jack. (Job Sheet #1)

## **FUNDAMENTALS OF HYDRAULICS UNIT II**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information, assignment, and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information and assignment sheets.
- F. Demonstrate and discuss the procedures outlined in the assignment and job sheets.
- G. Demonstrate how hydraulic pressure is calculated.
- H. Show examples of hydraulic jacks and assist students in identifying components.
- I. Let students practice operating hydraulic jack in order to understand operation.
- J. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Calculation of Hydraulic Pressure
  - 2. TM 2 — Basic Hydraulic Press
  - 3. TM 3 — Bernoulli's Theorem
  - 4. TM 4 — Block Diagram of Hydraulic System
  - 5. TM 5 — Operation of a Hydraulic Jack
- D. Assignment Sheet #1 — Draw a Block Diagram of a Simple Hydraulic System
- E. Job Sheet #1 — Disassemble, Clean, and Reassemble a Hydraulic Jack
- F. Test
- G. Answers to test

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1976.
- B. *Industrial Hydraulics Manual*. Troy, MI: Sperry Rand Corporation, 1970.

# FUNDAMENTALS OF HYDRAULICS

## UNIT II

### INFORMATION SHEET

#### I. Terms and definitions

- A. Hydraulics — The study of fluids in motion or at rest
- B. Fluid — A substance which has no shape of its own
- C. Pressure — The force exerted over a surface divided by its area
- D. Liquid — A fluid which is relatively incompressible  
(NOTE: A gas is a fluid that can be compressed.)
- E. Reservoir — A container for keeping a supply of working fluid in a hydraulic system
- F. Pump — A device which creates the flow of hydraulic fluid  
(NOTE: A pump converts mechanical energy into hydraulic energy.)
- G. Line — A tube, pipe, or hose for conducting a fluid
- H. Valve — A device which controls either pressure of fluid, direction of fluid flow, or rate of flow
- I. Actuator — A device which converts hydraulic energy into mechanical energy  
Example: Hydraulic cylinders  
Hydraulic motors
- J. Cylinder — An actuator which converts hydraulic energy into linear or rotary mechanical energy  
(NOTE: Rotary cylinders usually rotate less than one full revolution.)
- K. Motor — An actuator which converts hydraulic energy into rotary mechanical energy
- L. Cooler — An optional component that has a main function of cooling hydraulic fluid

#### II. Functions of hydraulic fluids

- A. Power transmission — Provides a medium for transferring force from one location to another

## INFORMATION SHEET

- B. Lubrication — Lessens friction on internal surfaces of hydraulic system components in order to reduce wear
- C. Sealing — Reduces flow through leakage paths
- D. Cooling — Provides a medium for removing heat generated in the system

### III. Calculation of pressure (Transparency 1)

- A. Determine force
- B. Determine area of surface to which force is applied
- C. Divide force by area of surface to which force is applied

(NOTE: Pressure is normally measured in units of pounds per square inch (PSI). Therefore, the force should be expressed in units of pounds, and area should be expressed in square inches.)

Example: If the force is four pounds, and the area equals 2 square inches, then the pressure will be 2 PSI.

### IV. Pascal's law — Pressure on a confined fluid is transmitted undiminished in every direction to the surface of the containing vessel

### V. Operating principles of a hydraulic press (Transparency 2)

(NOTE: The operation of a hydraulic press is an example of the application of Pascal's law.)

- A. A hydraulic press consists of two pistons supported by a quantity of hydraulic fluid
- B. A force on one piston creates a pressure in the hydraulic fluid equal to the force divided by the piston area
- C. Pascal's law states the pressure will be equal at all points within the fluid including the fluid at the second piston
- D. The force applied by the second piston is equal to the pressure times the area of the second cylinder

(NOTE: This is an example of force multiplication in a hydraulic system.)

### VI. Bernoulli's theorem (Transparency 3)

(NOTE: The following discussion does not take into account friction loss in the pipe.)

- A. Fluid flowing in a pipe will have some pressure and flow rate

## INFORMATION SHEET

- B. If the cross-sectional area of the pipe decreases, then the pressure will decrease

(NOTE: The flow rate will increase.)

- C. If the cross-sectional area increases to its original size, then the pressure will return to its original value

(NOTE: The flow rate will also return to its original value.)

### VII. Components of a basic hydraulic circuit (Transparency 4)

- A. Reservoir
- B. Pump
- C. Lines
- D. Valves (optional)
  - 1. Bypass valves
  - 2. Relief valves (cartridge valves)
  - 3. Control valves
  - 4. Check valves
- E. Actuator
  - 1. Motor
  - 2. Cylinder
- F. Cooler (optional)

### VIII. Power transfer in a hydraulic system

- A. Power is supplied into pump from
  - 1. Electric motor
  - 2. Gasoline or diesel engine
  - 3. Manual
- B. Mechanical power is converted to hydraulic power by the pump
- C. Hydraulic power is transmitted by lines

## INFORMATION SHEET

- D. Hydraulic power is regulated by valves
- E. Hydraulic power is converted to mechanical power by actuators
  - 1. Motor
  - 2. Cylinder

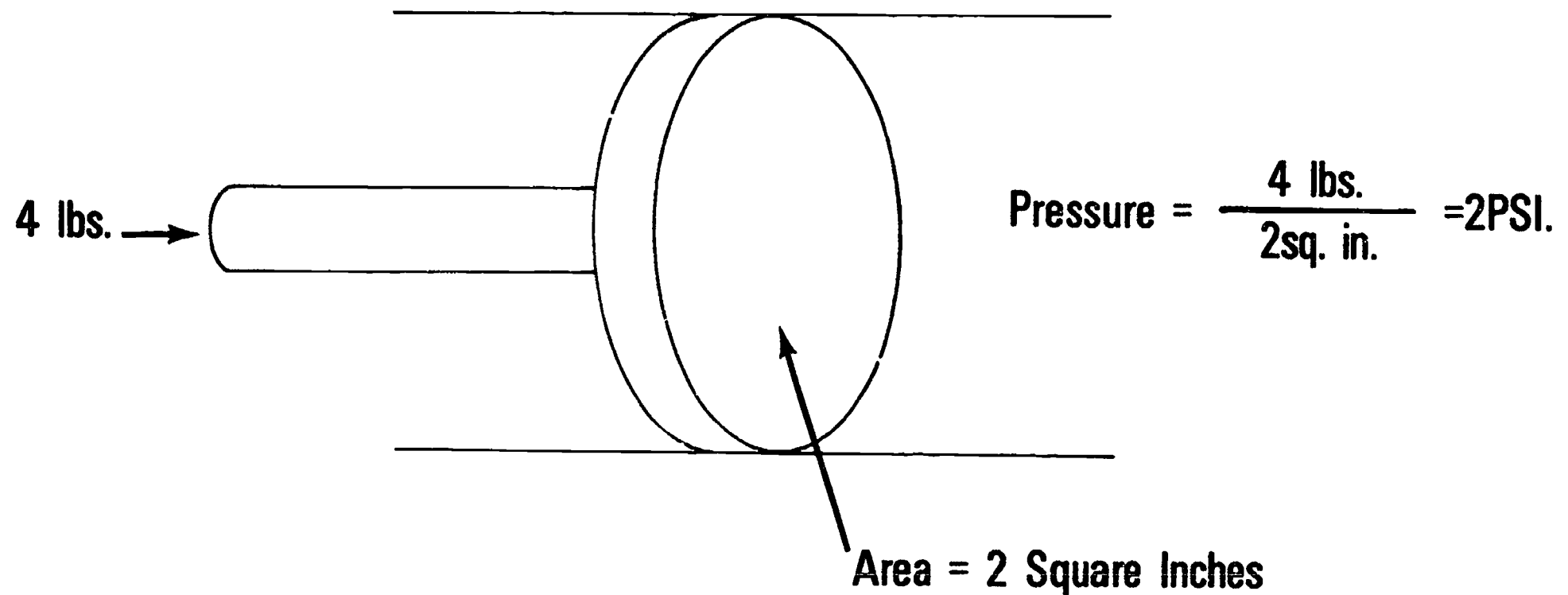
### IX. Components of a hydraulic jack (Transparency 5)

- A. Reservoir
- B. Pump
- C. Actuator (cylinder)
- D. Check valve 1
- E. Check valve 2
- F. Release valve

### X. Operation of a hydraulic jack (Transparency 5)

- A. Lifting
  - 1. Fluid is pulled from reservoir through check valve 1 on upward stroke of hand pump
  - 2. Check valve 2 is closed by a spring
  - 3. Fluid is forced past check valve 2 to cylinder to raise object on downward stroke of hand pump
  - 4. Check valve 1 is closed by a spring
- B. Lowering
  - 1. Release valve is opened to return fluid to reservoir
  - 2. Pumping with the release valve open causes fluid to circulate from reservoir to pump then back to reservoir

# Calculation of Hydraulic Pressure

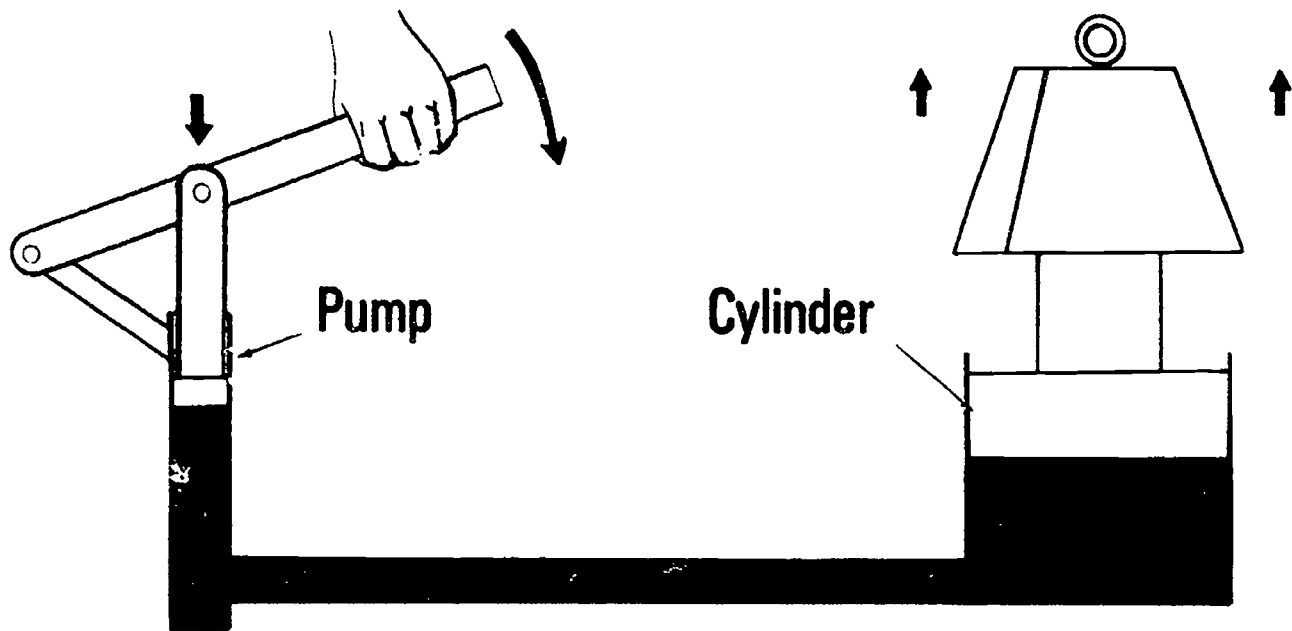


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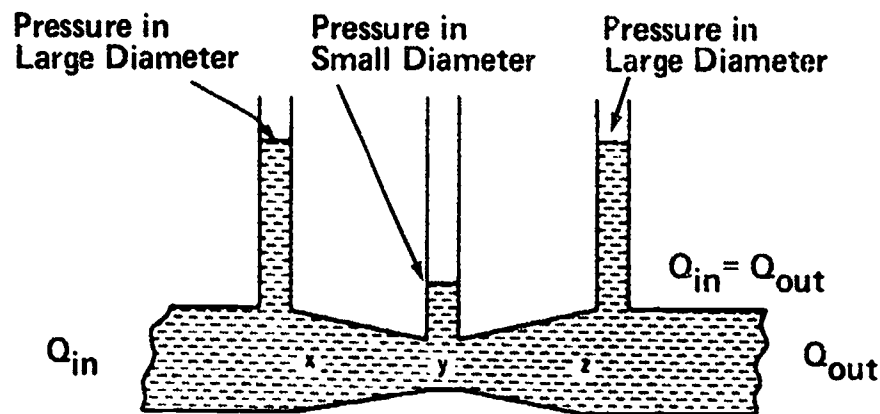
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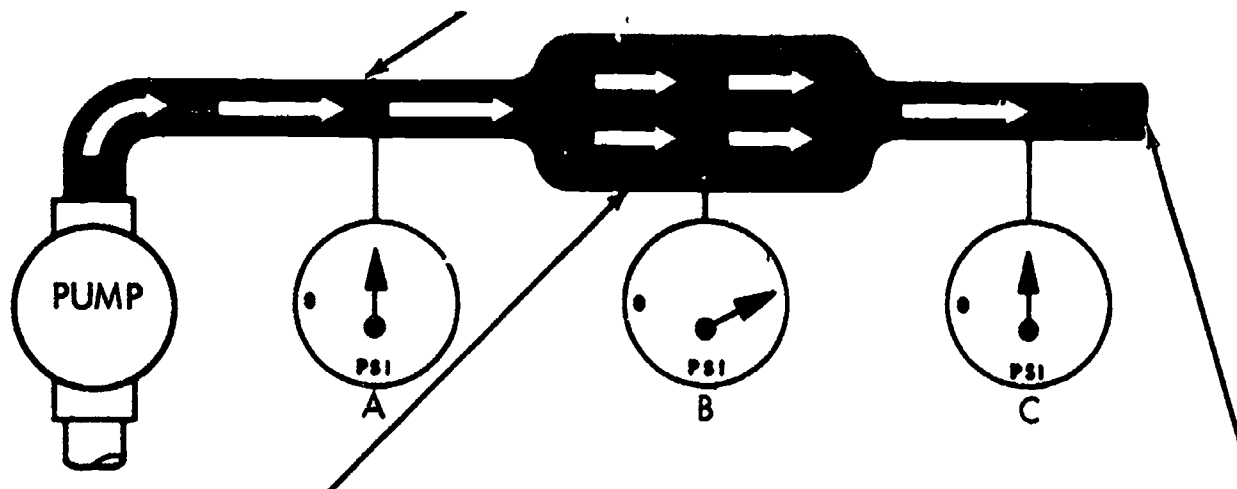
# Basic Hydraulic Press



# Bernoulli's Theorem



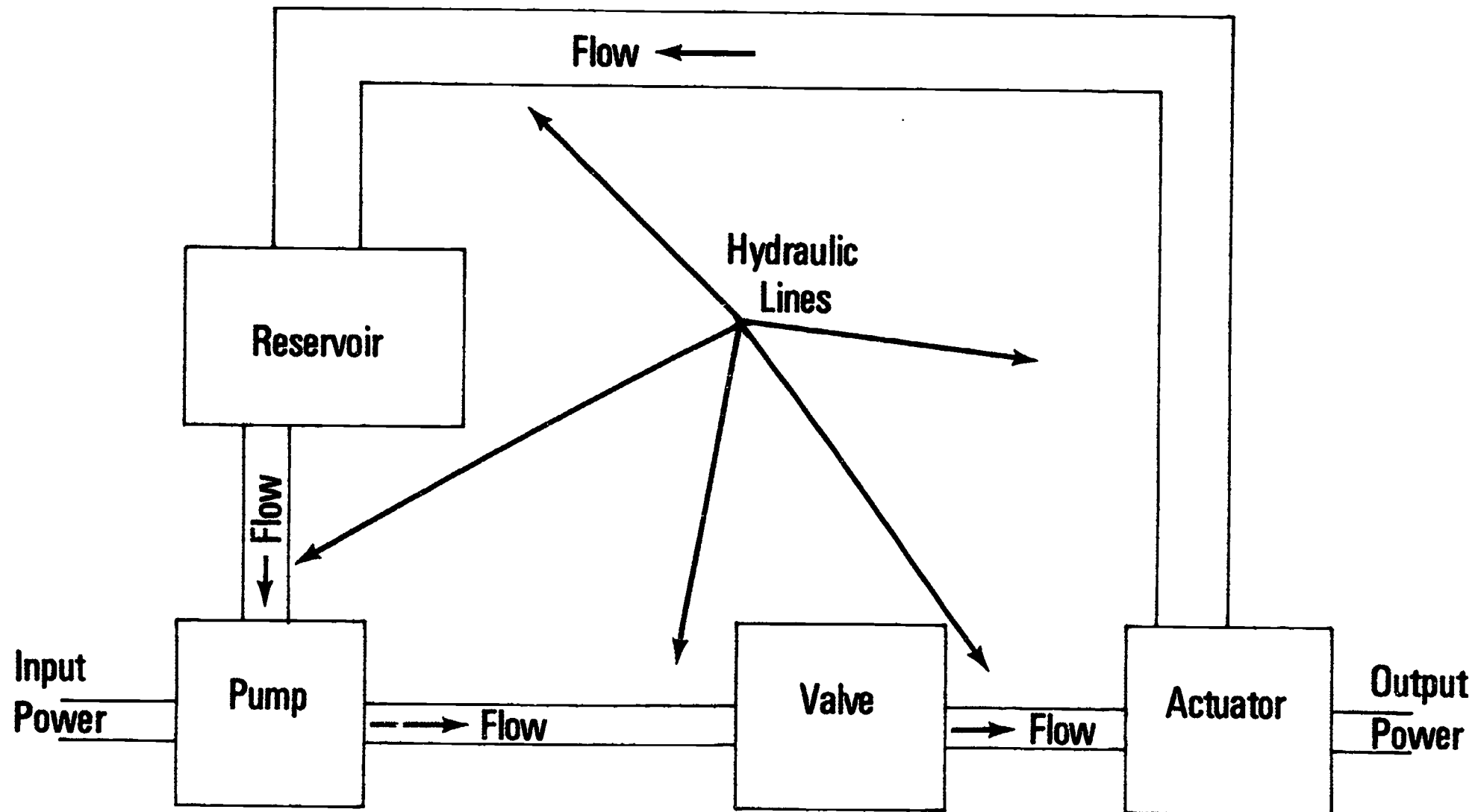
1. In the Small Section Pipe, Velocity is Maximum. More Energy is in the Form of Motion, So Pressure is Lower.



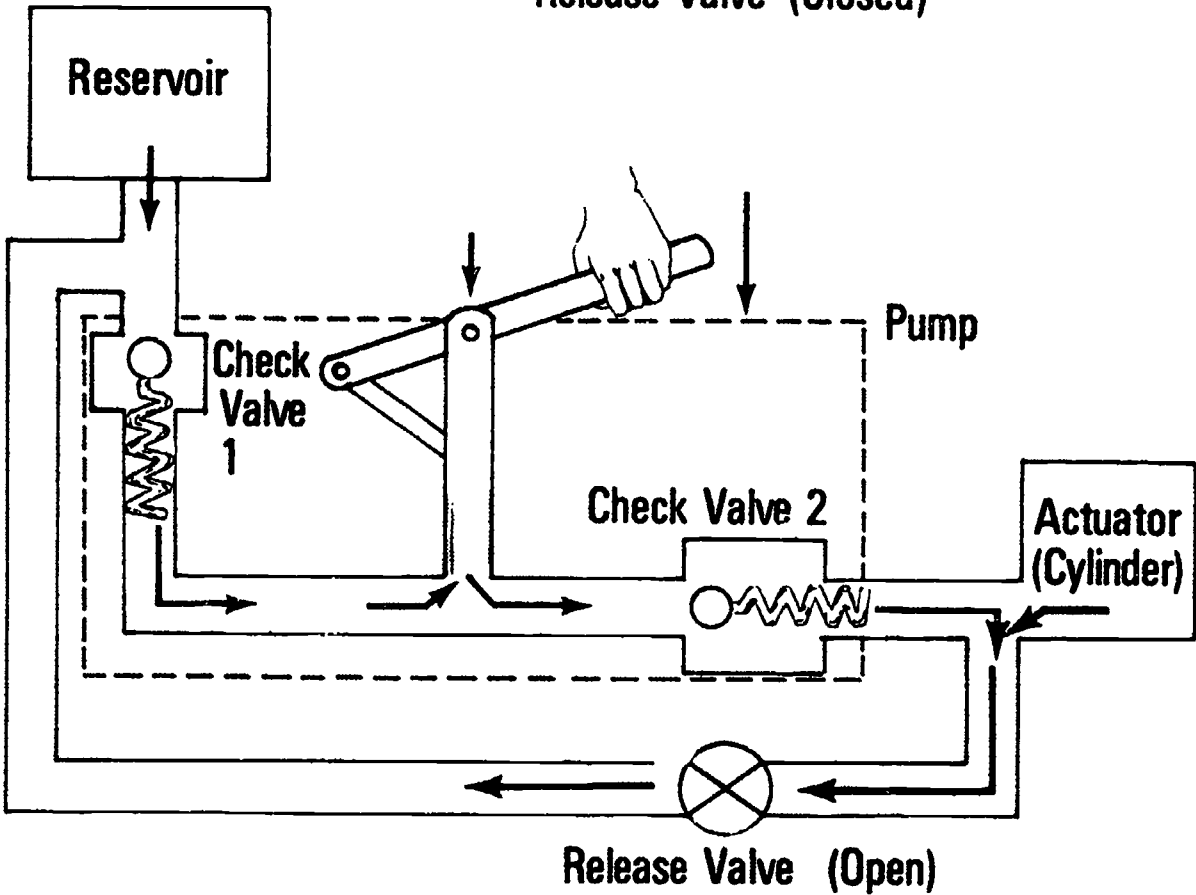
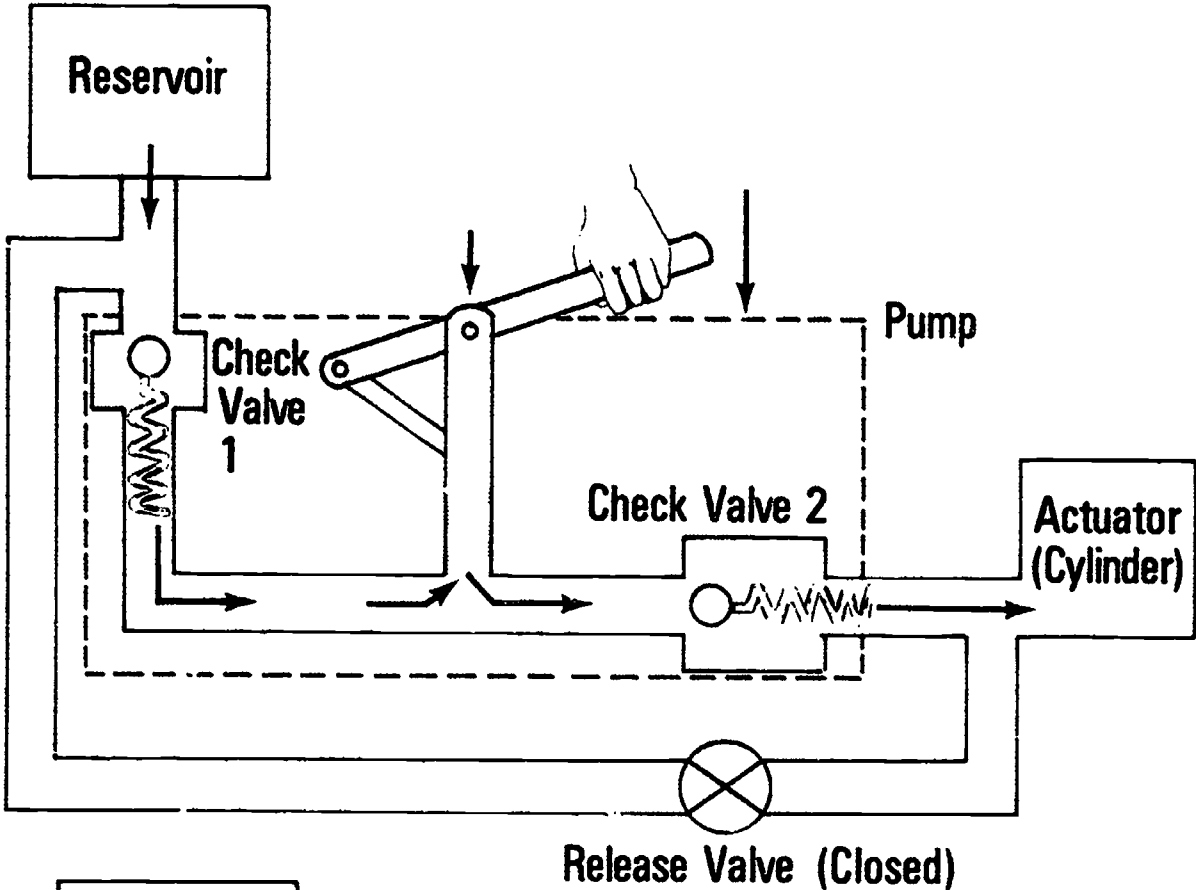
2. Velocity Decreases in the Larger Pipe. The Kinetic Energy Loss is Made Up by an Increase in Pressure.

3. Ignoring Friction Losses, the Pressure Again Becomes the Same as at "A" When the Flow Velocity Becomes the Same as at "A"

# Block Diagram of Hydraulic System



# Operation of a Hydraulic Jack



## **FUNDAMENTALS OF HYDRAULICS UNIT II**

### **ASSIGNMENT SHEET #1 — DRAW A BLOCK DIAGRAM OF A SIMPLE HYDRAULIC SYSTEM**

Directions: Draw a block diagram of a simple hydraulic system showing a reservoir, pump, valves, lines, and actuator. Designate flow direction by drawing arrows in the lines.

## **FUNDAMENTALS OF HYDRAULICS UNIT II**

### **JOB SHEET #1 — DISASSEMBLE, CLEAN, AND REASSEMBLE A HYDRAULIC JACK**

**A. Tools and materials**

1. Hydraulic jack
2. Hand tools
3. Lint free shop towels
4. Solvent
5. Hydraulic fluid for jack
6. Vise
7. Safety glasses

**B. Routine #1 — Disassemble jack**

1. Use the solvent to clean any dirt or grease from the external surfaces
2. Place the jack on a clean surface for disassembly
3. Remove the drain plug and drain oil from the jack
4. Remove the retaining nut which holds the ram (cylinder) in place
5. Remove the ram
6. Remove pumping piston
7. Remove the check valve balls and spring
8. Remove the release valve

☐ Have your instructor check your work

**C. Routine #2 — Clean and inspect the jack**

1. Use the solvent to clean all of the removed parts and housing internal surfaces
2. Inspect all surfaces for damage
3. Inspect seals for nicks and cuts

**JOB SHEET #1**

4. Replace seals

☐ Have your instructor check your work

**D. Routine #3 — Reassemble the jack**

1. Install the release valve
2. Install the check valve balls and spring
3. Make sure balls are properly seated and operate properly
4. Install pumping piston with seal
5. Install the ram with seal
6. Install the retaining ring
7. Fill with fluid

(NOTE: It may be necessary to bleed air from the jack.)

8. Test the operation of the jack

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

# FUNDAMENTALS OF HYDRAULICS

## UNIT II

NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with the correct definitions.

- |         |  |               |
|---------|--|---------------|
| _____a. | The study of fluids in motion or at rest   | 1. Line       |
| _____b. | A substance which has no shape of its own  | 2. Fluid      |
| _____c. | The force exerted over a surface divided by its area                                       | 3. Pump       |
| _____d. | A fluid which is relatively incompressible   | 4. Motor      |
| _____e. | A container for keeping a supply of working fluid in a hydraulic system                    | 5. Hydraulics |
| _____f. | A device which creates the flow of hydraulic fluid   | 6. Liquid     |
| _____g. | A tube, pipe, or hose for conducting a fluid   | 7. Reservoir  |
| _____h. | A device which controls either pressure of fluid, direction of fluid flow, or rate of flow | 8. Cylinder   |
| _____i. | A device which converts hydraulic energy into mechanical energy                            | 9. Pressure   |
| _____j. | An actuator which converts hydraulic energy into linear or rotary mechanical energy        | 10. Actuator  |
| _____k. | An actuator which converts hydraulic energy into rotary mechanical energy                  | 11. Valve     |
| _____l. | An optional component that has the main function of cooling hydraulic fluid                | 12. Cooler    |

2. Discuss briefly four functions of hydraulic fluids.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_



**TEST**

3. Calculate pressure in the following problems when given area and force.

a. Force = 100 lbs., Area = 10 square inches

b. Force = 10 lbs., Area = 1 square inch

c. Force = 5 lbs., Area =  $\frac{1}{2}$  square inch

4. State Pascal's law. \_\_\_\_\_

\_\_\_\_\_

5. Explain the operating principles of a hydraulic press.

a. \_\_\_\_\_

\_\_\_\_\_

b. \_\_\_\_\_

\_\_\_\_\_

c. \_\_\_\_\_

\_\_\_\_\_

d. \_\_\_\_\_

\_\_\_\_\_

6. Discuss Bernoulli's theorem.

a. \_\_\_\_\_

\_\_\_\_\_

b. \_\_\_\_\_

\_\_\_\_\_

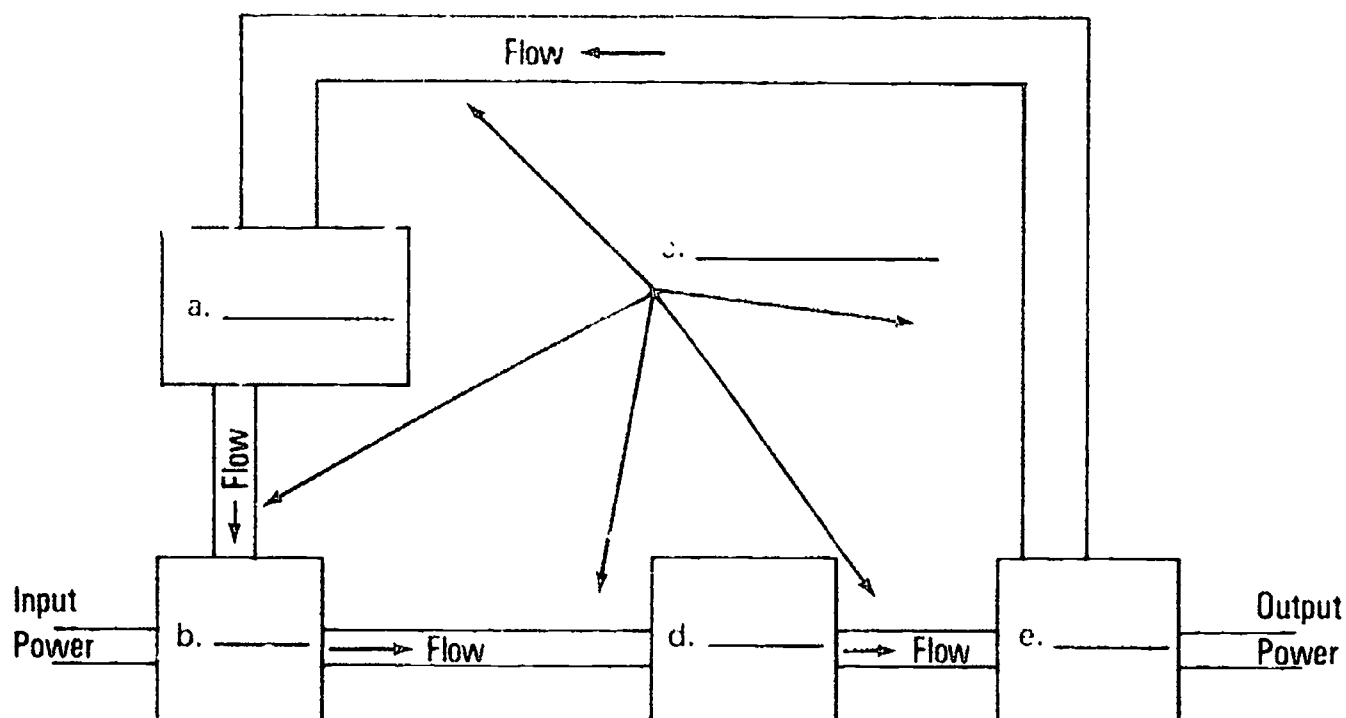
c. \_\_\_\_\_

\_\_\_\_\_

## TEST

7. Identify the components of a basic hydraulic circuit.

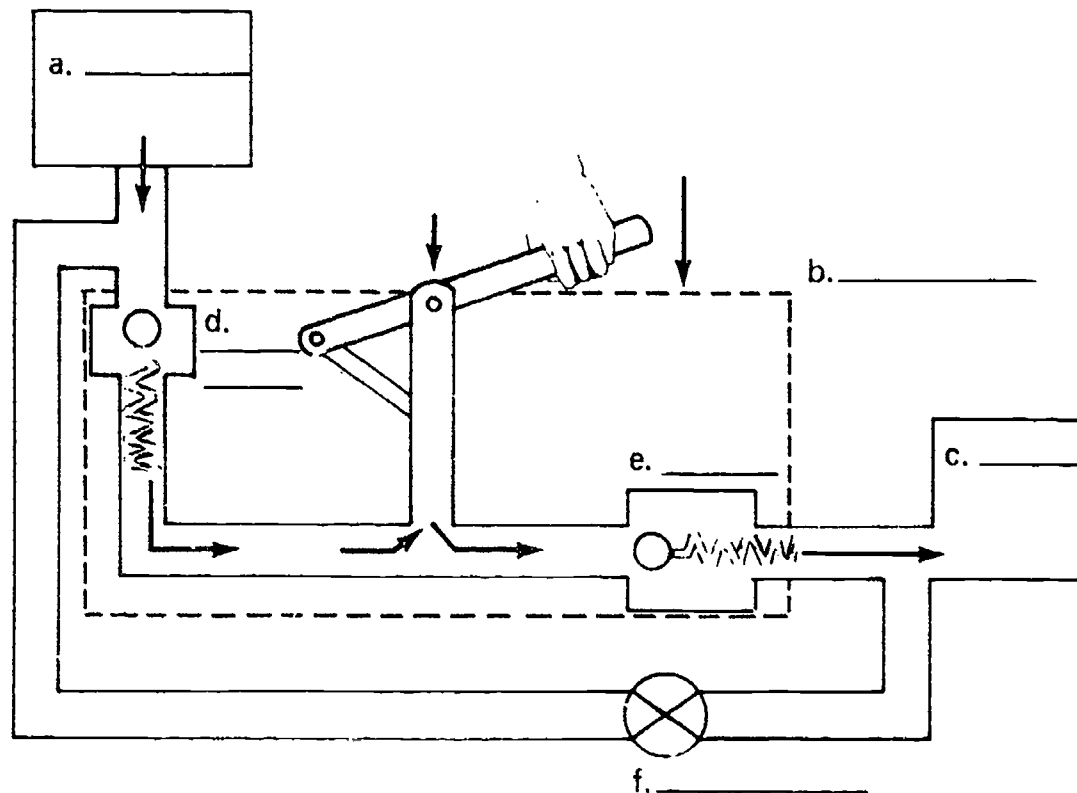
### Block Diagram of Hydraulic System



8. Select true statements concerning the power transfer in a hydraulic system by placing an "X" in the appropriate blanks.
- \_\_\_\_ a. Power is supplied into the pump from the reservoir
  - \_\_\_\_ b. Mechanical power is converted to hydraulic power by the pump
  - \_\_\_\_ c. Hydraulic power is transmitted by lines
  - \_\_\_\_ d. Hydraulic power is regulated by actuators
  - \_\_\_\_ e. Hydraulic power is converted to mechanical power by actuators

## TEST

9. Identify the components of a hydraulic jack.



10. Distinguish between the lifting and lowering operation of a hydraulic jack by placing an "X" next to the description of the lowering operation.

- \_\_\_\_\_ a.    1) Release valve is opened to return fluid to reservoir  
               2) Pumping with the release valve open causes fluid to circulate from reservoir to pump then back to reservoir
- \_\_\_\_\_ b.    1) Fluid is pulled from reservoir through check valve 1 on upward stroke of hand pump  
               2) Check valve 2 is closed by a spring  
               3) Fluid is forced past check valve 2 to cylinder to raise object on downward stroke of hand pump  
               \_\_\_\_\_ Check valve 1 is closed by a spring

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

11. Draw a block diagram of a simple hydraulic system.
12. Demonstrate the ability to disassemble, clean, inspect, and reassemble a hydraulic jack.

## FUNDAMENTALS OF HYDRAULICS UNIT II

### ANSWERS TO TEST

1.   a.    5                   e.    7                   i.    10  
      b.    2                   f.    3                   j.    8  
      c.    9                   g.    1                   k.    4  
      d.    6                   h.    11                  l.    12
  
2.   Discussion should include:
  - a.    Power transmission — Provides a medium for transferring force from one location to another
  - b.    Lubrication — Lessens friction on internal surfaces of hydraulic system components in order to reduce wear
  - c.    Sealing — Reduces flow through leakage paths
  - d.    Cooling — Provides a medium for removing heat generated in the system
  
3.   a.    10 PSI  
      b.    10 PSI  
      c.    10 PSI
  
4.   Pressure on a confined fluid is transmitted undiminished in every direction to the surface of the containing vessel
  
5.   Explanation should include:
  - a.    A hydraulic press consists of two pistons supported by a quantity of hydraulic fluid
  - b.    A force on one piston creates a pressure in the hydraulic fluid equal to the force divided by the piston area
  - c.    Pascal's law states the pressure will be equal at all points within the fluid including the fluid at the second piston
  - d.    The force applied by the second piston is equal to the pressure times the area of the second cylinder
  
6.   Discussion should include:
  - a.    Fluid flowing in a pipe will have some pressure and flow rate
  - b.    If the cross-sectional area of the pipe decreases, then the pressure will decrease
  - c.    If the cross-sectional area increases to its original size, then the pressure will return to its original value
  
7.   a.    Reservoir  
      b.    Pump  
      c.    Lines  
      d.    Valve  
      e.    Actuator
  
8.   b, c, e

**ANSWERS TO TEST**

- 9.
  - a. Reservoir
  - b. Pump
  - c. Actuator
  - d. Check valve 1
  - e. Check valve 2
  - f. Release valve
- 10. a
- 11. Performance skills evaluated to the satisfaction of the instructor
- 12. Performance skills evaluated to the satisfaction of the instructor

## **RESERVOIRS UNIT III**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to select reasons for using a pressurized reservoir and functions of a reservoir. The student should also be able to draw symbols for reservoirs and clean and inspect a reservoir. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student will be able to:

1. Define reservoir.
2. Name two types of reservoirs.
3. Select reasons for using a pressurized reservoir.
4. Select functions of a reservoir.
5. Identify the parts of a properly designed, vented reservoir.
6. Identify the parts of a properly designed, pressurized reservoir.
7. Draw the symbol for a vented and pressurized reservoir.
8. Demonstrate the ability to clean and inspect a vented reservoir. (Job Sheet #1)

## **RESERVOIRS UNIT III**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheet.
- G. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Parts of a Properly Designed, Vented Reservoir
  - 2. TM 2 — Parts of a Properly Designed, Pressurized Reservoir
- D. Job Sheet #1 — Clean and Inspect a Vented Reservoir
- E. Test
- F. Answers to test

### **REFERENCES USED IN DEVELOPING THIS UNIT**

- A. *Fluid Power I*. Cleveland, OH: Parker-Hannifin Corporation, 1979.
- B. *Fundamentals of Service*. Moline, IL: Deere and Company, 1967.
- C. *Industrial Hydraulics Manual*. Troy, MI: Sperry Rand Corporation, 1970.

## **RESERVOIRS UNIT III**

### **INFORMATION SHEET**

- I. Reservoir** — Container for holding a supply of fluid
- II. Types of reservoirs**
  - A. Vented to atmosphere
  - B. Pressurized and sealed
- III. Reasons for using a pressurized reservoir**
  - A. Contamination is reduced
  - B. Condensation is reduced  
(NOTE: Some condensation is almost always present, especially in high humidity conditions.)
  - C. Helps to force fluids to the pump
- IV. Functions of a reservoir**
  - A. Provides fluid to replace system leakage
  - B. Contains excess fluid resulting from system volume changes  
(NOTE: System volume changes occur when a cylinder is retracted or extended.)
  - C. Helps to cool system
  - D. Helps to separate dirt and air from fluid
- V. Parts of a properly designed, vented reservoir (Transparency 1)**
  - A. Filler cap
  - B. Fluid level gauge
  - C. Baffle
    - 1. Separation baffle helps separate inlet fluid from outlet fluid and aids in air and dirt separation and cooling  
(NOTE: A separation baffle is used on almost all systems.)



## INFORMATION SHEET

2. Pressure baffle prevents oil from being forced through a vent under pressures and is used only on systems that are vented

D. Reservoir outlet

(NOTE: The reservoir outlet goes to the pump.)

E. Return lines

F. intake filter screen

(NOTE: The intake filter screen protects the pump.)

G. Drain plug

(NOTE: Some drain plugs are magnetic to help remove metal chips in fluid.)

H. Inspection plate

### VI. Parts of a properly designed, pressurized reservoir (Transparency 2)

A. Filler cap

B. Fluid level gauge

C. Baffle

D. Reservoir outlet

E. Return lines

F. Intake filter screen

G. Drain plug

H. Inspection plate

I. Pressure regulator

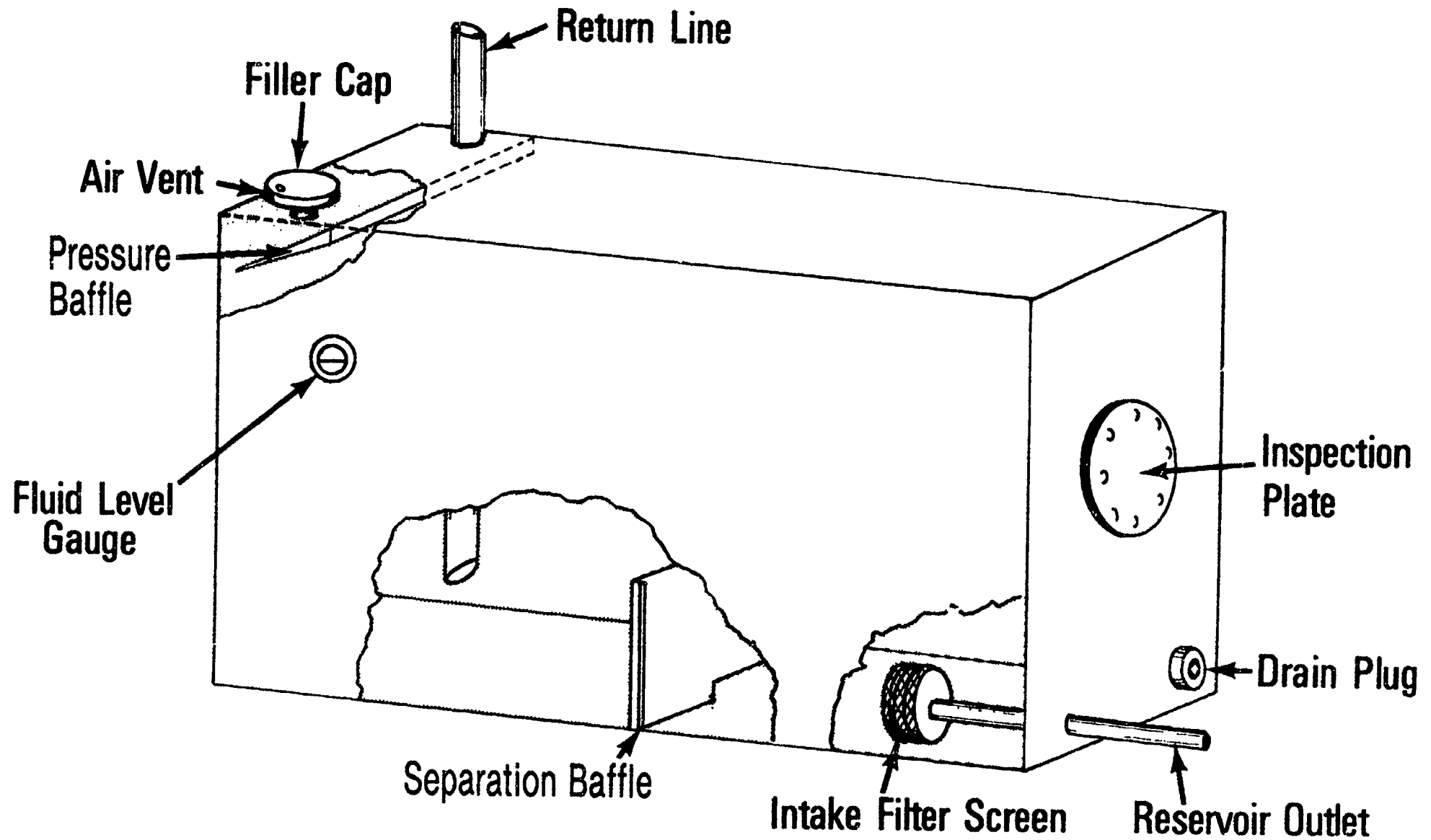
J. Air line

### VII. Symbols for reservoirs

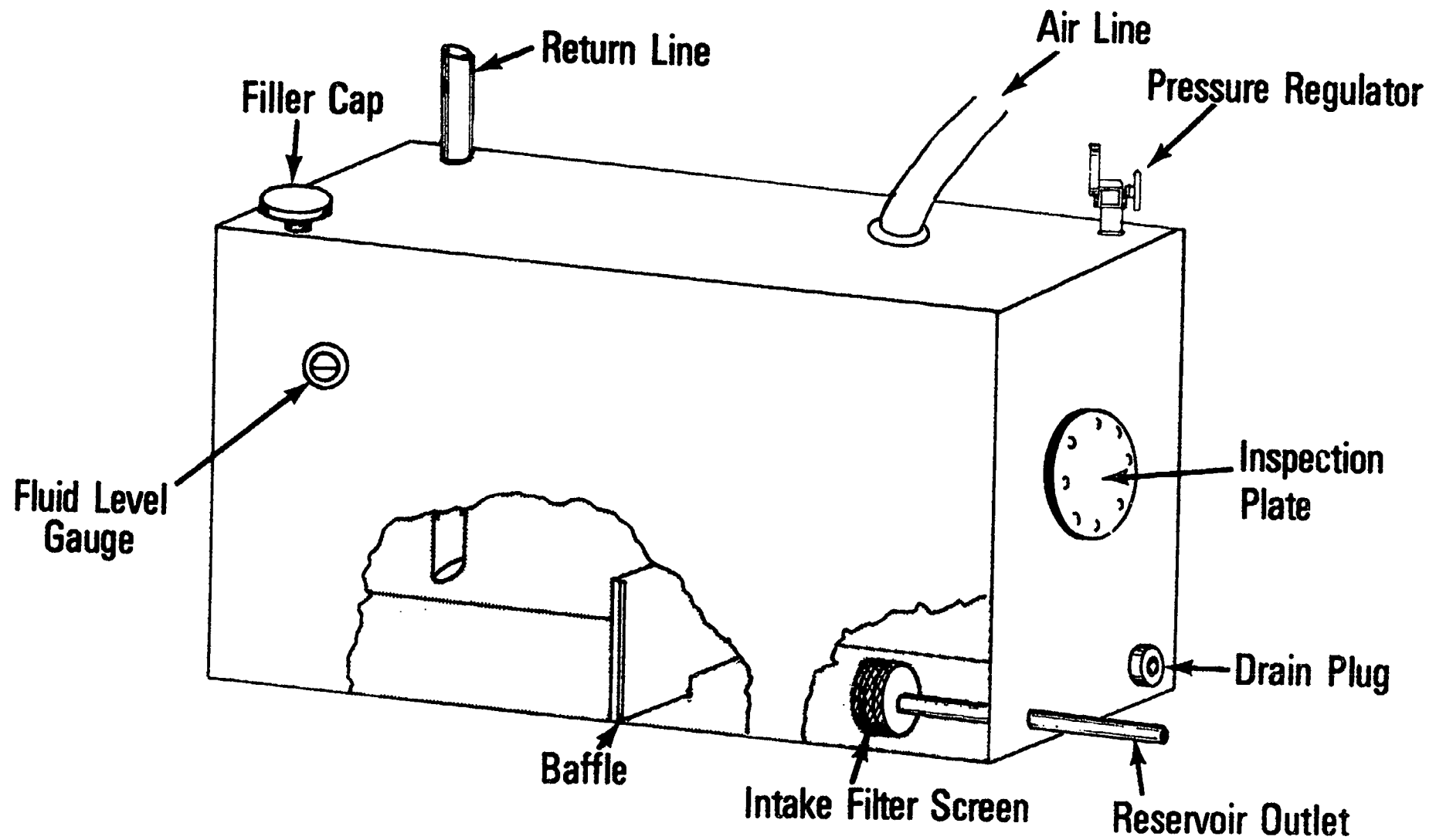
A. Vented 

B. Pressurized 

# Parts of a Properly Designed, Vented Reservoir



# Parts of a Properly Designed, Pressurized Reservoir



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## RESERVOIRS UNIT III

### JOB SHEET #1 — CLEAN AND INSPECT A VENTED RESERVOIR

**A. Tools and materials**

1. Wrenches (as required)
2. Screwdriver (as required)
3. Vented reservoir
4. Lint-free shop towel
5. Solvent
6. Safety glasses

**B. Routine #1 — Clean reservoir**

1. Drain fluid
2. Remove inspection plate
3. Remove sludge on bottom of reservoir with cloth wetted with solvent
4. Clean air vent

(NOTE: Inspect relief valve on pressurized reservoir.)

5. Clean intake filter screen with solvent
6. Rinse inside of reservoir with solvent

**C. Routine #2 — Inspect reservoir**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine reservoir for leaks, cracks, and broken welds		
2. Inspect inlet filter screen; replace if damaged		
3. Inspect filler cap to insure proper operation		
4. Check air vent to insure that it is not plugged		
5. Check operation of relief valve		

**JOB SHEET #1**

- ☐ Have your instructor check your work
- 6. Clean up area and return tools and materials to proper storage

## RESERVOIRS UNIT III

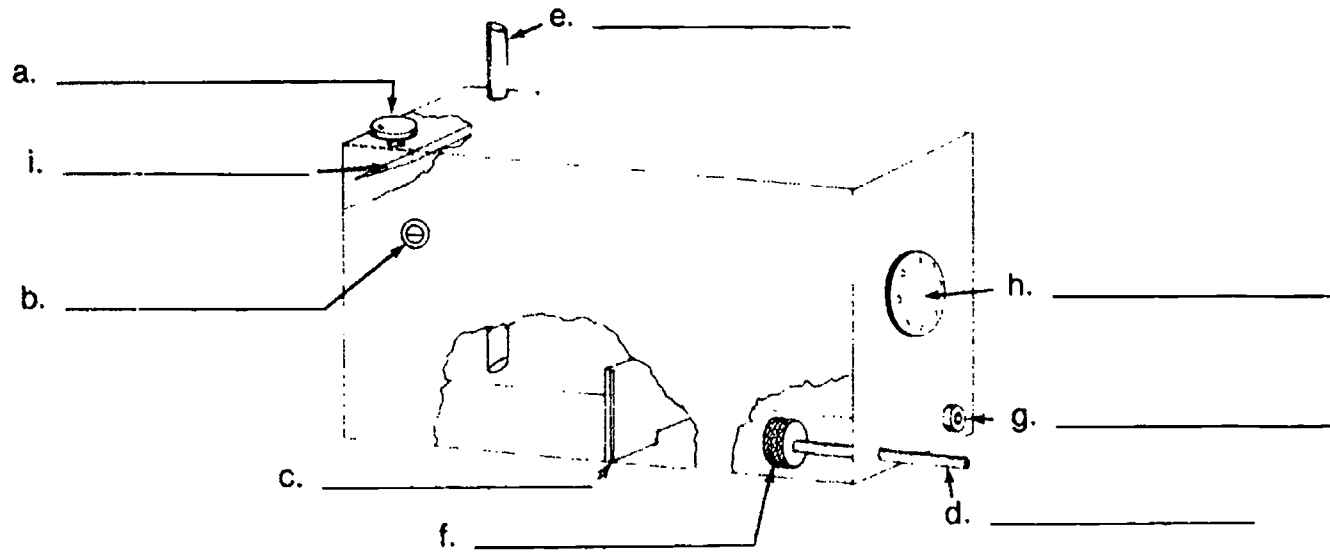
NAME \_\_\_\_\_

### TEST

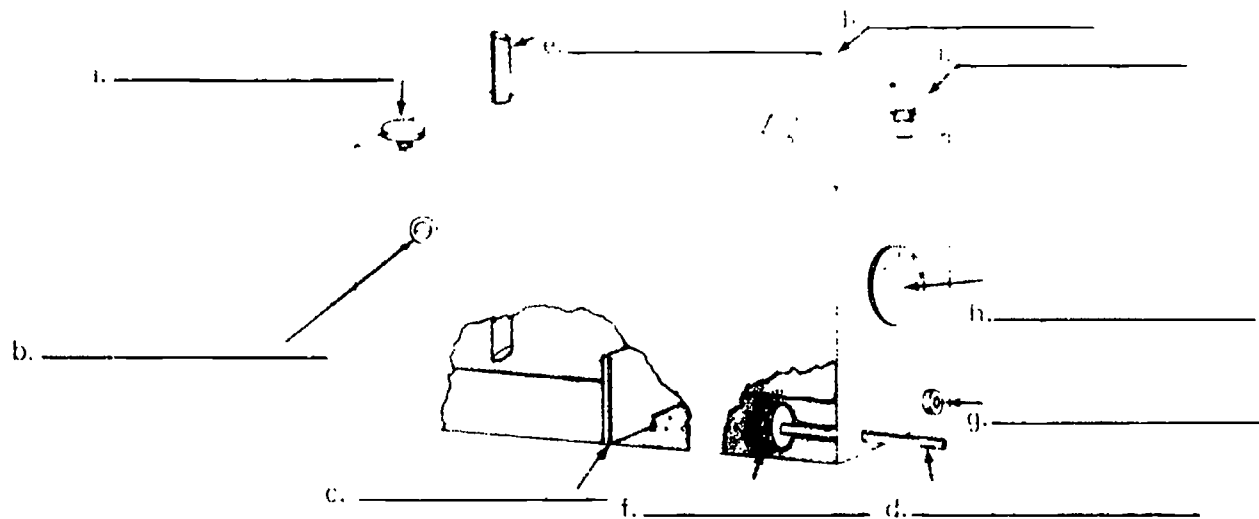
1. Define reservoir. \_\_\_\_\_  
\_\_\_\_\_
2. Name two types of reservoirs.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
3. Select reasons for using a pressurized reservoir by placing an "X" in the appropriate blanks.
  - \_\_\_\_a.     Condensation is increased
  - \_\_\_\_b.     Contamination is reduced
  - \_\_\_\_c.     Helps to force the fluid to the baffle
  - \_\_\_\_d.     Condensation is reduced
  - \_\_\_\_e.     Helps to force fluids to the pump
4. Select functions of a reservoir by placing an "X" in the appropriate blanks.
  - \_\_\_\_a.     Helps to cool system
  - \_\_\_\_b.     Contains excess fluid resulting from system volume changes
  - \_\_\_\_c.     Connects main components of system
  - \_\_\_\_d.     Helps to separate dirt and air from fluid
  - \_\_\_\_e.     Provides mechanical action for movement of fluid
  - \_\_\_\_f.     Provides fluid to replace system leakage

# TEST

5. Identify the parts of a properly designed, vented reservoir.



6. Identify the parts of a properly designed, pressurized reservoir.



**TEST**

7. Draw the symbols for reservoirs.

a. Vented

b. Pressurized



(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

8. Demonstrate the ability to clean and inspect a vented reservoir.



## RESERVOIRS UNIT III

### ANSWERS TO TEST

1. Container for holding a supply of fluid
2. a. Vented to atmosphere  
b. Pressurized and sealed
3. b, d, e
4. a, b, d, f
5. a. Filler cap  
b. Fluid level gauge  
c. Separation baffle  
d. Reservoir outlet  
e. Return line  
f. Intake filter screen  
g. Drain plug  
h. Inspection plate  
i. Pressure baffle
6. a. Filler cap  
b. Fluid level gauge  
c. Baffle  
d. Reservoir outlet  
e. Return line  
f. Intake filter screen  
g. Drain plug  
h. Inspection plate  
i. Pressure regulator  
j. Air line
7. a.   
  
b. 
8. Performance skills evaluated to the satisfaction of the instructor

# **LINES, FITTINGS, AND COUPLERS**

## **UNIT IV**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to select true statements concerning the characteristics of steel pipe and hydraulic hose and discuss the types, construction, and size of steel tubing. The student should also be able to identify hose-ends and fittings used in hydraulic systems and replace a reusable hose end. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student will be able to:

1. Match terms related to lines, fittings, and couplers with their correct definitions.
2. Select true statements concerning the characteristics of steel pipe.
3. Discuss the types, construction, and size of steel tubing.
4. Select true statements concerning the characteristics of hydraulic hose.
5. Identify types of fittings commonly used with tubing.
6. Identify types of hose-ends used in hydraulic systems.
7. Identify types of fittings used in hydraulic systems.
8. Select factors to consider when routing tubing in hydraulic systems.
9. List conditions to avoid when routing hydraulic hose.
10. Demonstrate the ability to replace a reusable hose end. (Job Sheet #1)

## **LINES, FITTINGS, AND COUPLERS UNIT IV**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
  - B. Provide students with information and job sheets.
  - C. Make transparencies.
  - D. Discuss unit and specific objectives.
  - E. Discuss information sheet.
- Demonstrate and discuss the procedures outlined in the job sheet.
- G. Show students examples of lines, fittings, and couplers, and discuss safety precautions which should be practiced when working with them.
  - H. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Sizing of Steel Pipe
  - 2. TM 2 — Working Pressure for Steel Pipe
  - 3. TM 3 — Hose Construction and Hose Types
  - 4. TM 4 — Types of Fittings Commonly Used with Tubing
  - 5. TM 5 — Types of Hose Ends
  - 6. TM 6 — Types of Fittings Used in Hydraulic Systems
  - 7. TM 7 — Routing Hydraulic Hose and Tubing
- D. Job Sheet #1 — Replace a Reusable Hose End
- E. Test
- F. Answers to test

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fluid Power I.* Cleveland, OH: Parker-Hannifin Corporation, 1979.
- B. *Fundamentals of Service.* Moline, IL: Deere and Company, 1967.
- C. *Industrial Hydraulics Manual.* Troy, MI: Sperry Rand Corporation, 1970.

# **LINES, FITTINGS, AND RESERVOIRS**

## **UNIT IV**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Pipe — Rigid fluid conductor which is not intended to be bent or shaped
- B. Tubing — A semi-rigid fluid conductor which is customarily bent into a desired shape
- C. Hose — Flexible fluid conductor which can readily bend with movement of machine members
- D. Hose end — A fitting which is attached onto a hose to allow the hose to be connected to other components
- E. Fittings — A device for connecting hydraulic components, such as a hose to a valve
- F. Joint Industrial Council — An organization which is responsible for promotion of industrial standards

(NOTE: JIC is the abbreviation for the Joint Industrial Council.)

- G. Skive — To remove the outer covering on a hose

#### **II. Characteristics of steel pipe**

(NOTE: Do not use galvanized pipe in hydraulic systems.)

- A. Size (Transparency 1)
  - 1. Size typically specified by nominal inside diameter
  - 2. Wall thickness (for a given size) is described by a schedule number
- B. Pressure range (Transparency 2)
  - 1. Schedule 40 is commonly used for low pressure lines
  - 2. Schedule 80 is commonly used for high pressure lines
  - 3. Schedule 160 is commonly used for very high pressure lines

#### **III. Characteristics of steel tubing**

- A. Types
  - 1. Stainless
  - 2. Nonstainless

## INFORMATION SHEET

### B. Construction

1. Seamless
2. Welded

### C. Size (Table 1)

TUBE OD	WALL THICKNESS	TUBE ID
$\frac{1}{8}$	0.028	0.069
	.032	.061
	.035	.055
$\frac{3}{16}$	0.032	0.1235
	.035	.1175

Table 1

1. Indicated by (actual) outside diameter and wall thickness
2. Wall thickness sometimes described as:
  - a. Thin wall (low pressure)
  - b. Standard (intermediate pressure)
  - c. Thick wall (very high pressure)

## IV. Characteristics of hydraulic hose

### A. Construction (Transparency 3)

1. Inner tube
2. Reinforcement
  - a. Wire braid for high pressure applications
  - b. Fiber braid for low pressure applications
3. Cover

### B. Size

1. Factors to specify
  - a. Inside diameter
  - b. Working pressure
  - c. Construction

## INFORMATION SHEET

### 2. Standard hose types (Transparency 3)

- a. Standard developed by Society of Automotive Engineers (SAE)
- b. Hoses are guaranteed by the manufacturer to meet a minimum safety standard

### V. Types of fittings commonly used with tubing (Transparency 4)

#### A. Flare (JIC 37° flare or 45° flare)

(NOTE: The end of the tubing is flared to mate with a fitting. 37° is most common and 45° is used in some low pressure applications.)

#### B. Flareless

##### 1. Swage type

(NOTE: The tubing material is compressed to form a build-up of tubing material around a retaining ring. This ring is used to hold the fitting on the tubing.)

##### 2. Bite type

(NOTE: A retaining ring is compressed onto the tube. The ring "bites" into the tubing. The primary difference between these two types of fittings is that the swage type displaces the tubing to conform around the retaining ring. The bite type cuts or bites into the tubing.)

#### C. Braze-on

(NOTE: The fitting is brazed or welded onto the end of the tubing.)

### VI. Types of hose-ends used in hydraulic systems (Transparency 5)

#### A. Permanent

(NOTE: The fitting is crimped or swaged onto the hose.)

#### B. Reusable

##### 1. No-skive

(NOTE: The hose cover is not removed. The hose-end nipple is inserted into the hose. A socket (sleeve) is screwed or pushed onto the hose-end to clamp it to the hose.)

##### 2. Skive

(NOTE: The hose cover is removed (skived) prior to the installation of the hose end. The installation is the same as the no-skive.)

## INFORMATION SHEET

### 3. Clamp-on

(NOTE: A barbed hose-end nipple is inserted into hose and a clamp is bolted onto the hose to provide grip.)

### 4. JIC

## VII. Types of fittings used in hydraulic systems (Transparency 6)

### A. Pipe thread

### B. Straight thread

(NOTE: Straight thread should be used with an O-ring.)

### C. Flare

### D. Split flange

## VIII. Factors to consider when routing tubing in hydraulic systems

### A. Avoid straight-line hook-ups

(NOTE: These do not allow expansion and contraction.)

### B. Use the fewest and simplest bends possible

### C. Support long runs of tubing

### D. Avoid interference with operator controls

## IX. Conditions to avoid when routing hydraulic hose (Transparency 7)

### A. Taut hose

### B. Loops

### C. Twists

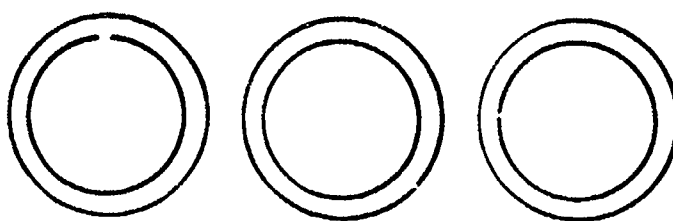
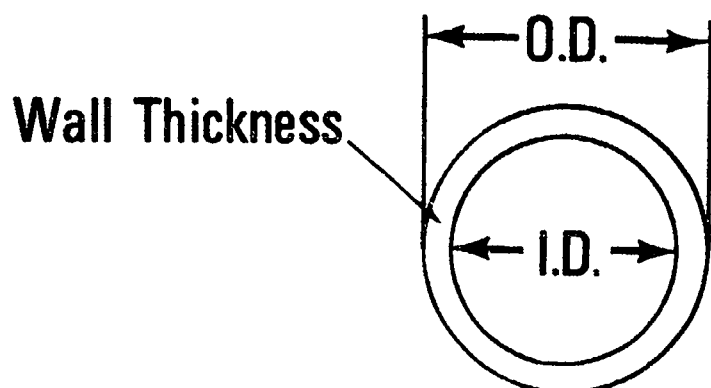
### D. Rubbing

### E. Heat

### F. Sharp bends



# Sizing of Steel Pipe



Schedule 40    Schedule 80    Schedule 160

Nominal Size	Pipe O.D.	INSIDE DIAMETER		
		Schedule 40	Schedule 80	Schedule 160
1/8	.405	.269	.215	
1/4	.540	.364	.302	
3/8	.675	.493	.423	
1/2	.840	.622	.564	.466
3/4	1.050	.824	.742	.587
1	1.315	1.049	.957	.815
1 1/4	1.660	1.380	1.278	1.160
1 1/2	1.900	1.610	1.500	1.338
2	2.375	2.067	1.939	1.689
2 1/2	2.875	2.469	2.323	2.125
3	3.500	3.068	2.900	2.624

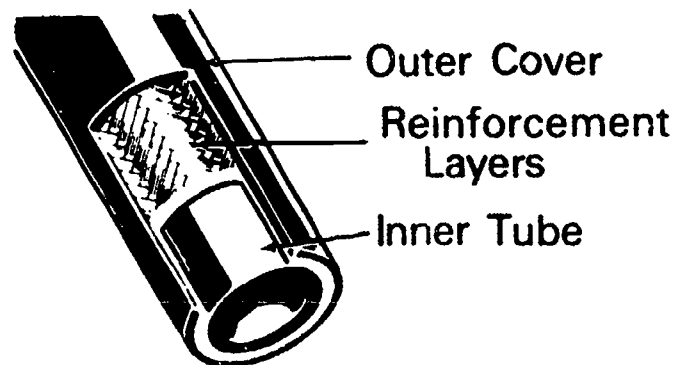
# Working Pressure for Steel Pipe

Working Pressure (PSI)  
(Burst Pressure)

Nominal Size	Schedule 40	Schedule 80	Schedule 160
1/8	3500 (20,200)	4800 (28,000)	—
1/4	2100 (19,500)	4350 (26,400)	—
3/8	1700 (16,200)	3800 (22,500)	—
1/2	2300 (15,600)	4100 (21,000)	7300 (26,700)
3/4	2000 (12,900)	3500 (17,600)	8500 (25,000)
1	2100 (12,100)	3500 (15,900)	5700 (22,300)
1 1/4	1800 (10,100)	3000 (13,900)	4400 (18,100)
1 1/2	1700 (9,100)	2800 (12,600)	4500 (17,700)
2	1500 (7,800)	2500 (11,000)	4600 (17,500)

# Hose Construction and Hose Types

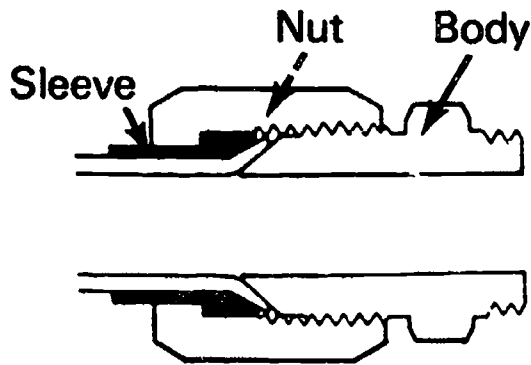
SAE Number	Inner Tube	Reinforcement	Cover
SAE 100R1	Synthetic Rubber	1 High Tensile Steel	Synthetic Rubber
SAE 100R2	Synthetic Rubber	2 Wire Braids 2 Spiral Plies and 1 Wire Braid	Synthetic Rubber
SAE 100R3	Synthetic Rubber	2 Textile Braids	Synthetic
SAE 100R4	Synthetic Rubber	Braided Textile Fibers/ Spiral Body Wire	Synthetic
SAE 100R5	Synthetic Rubber	1 Textile Braid a High Tensile Steel Wire Braid	Cotton Braid
SAE 100R6	Synthetic Rubber	1 Textile Braid	Synthetic Rubber
SAE 100R7	Thermoplastic	Synthetic Fiber	Thermoplastic
SAE 100R8	Thermoplastic	Synthetic Fiber	Thermoplastic
SAE 100R9	Synthetic Rubber	4 Spiral Plies Wrapped In Alternating Directions	Synthetic Rubber
SAE 100R10	Synthetic Rubber	4 Spiral Plies of Heavy Wire Wrapped in Alternating Directions	
SAE 100R11	Synthetic Rubber	6 Spiral Plies of Heavy Wire Wrapped in Alternating Directions	Synthetic Rubber



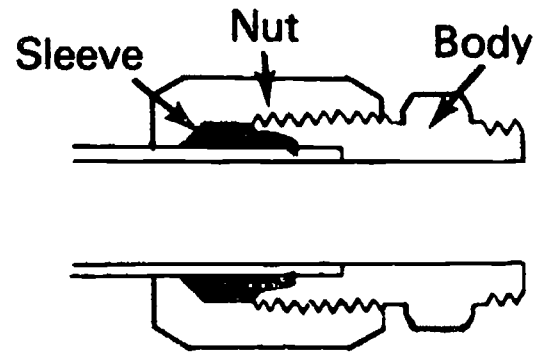
Flexible Hose Construction

SAE Hose Types

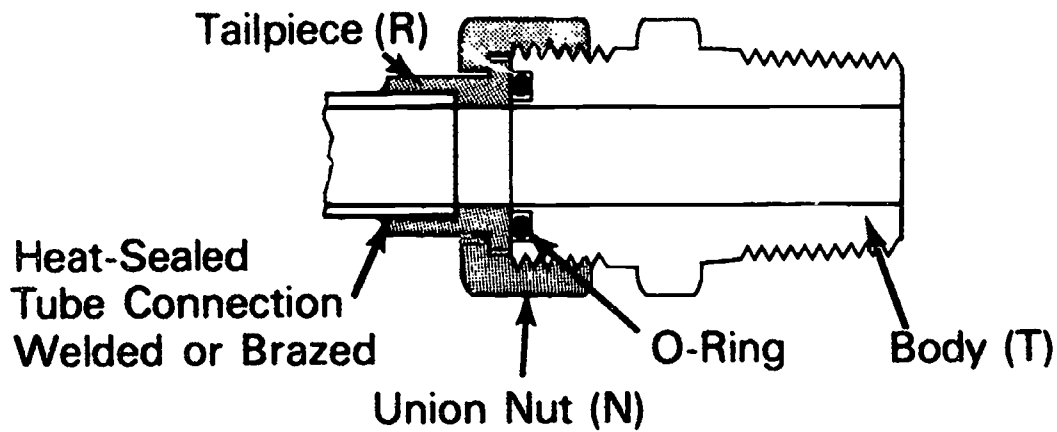
# Types of Fittings Commonly Used with Tubing



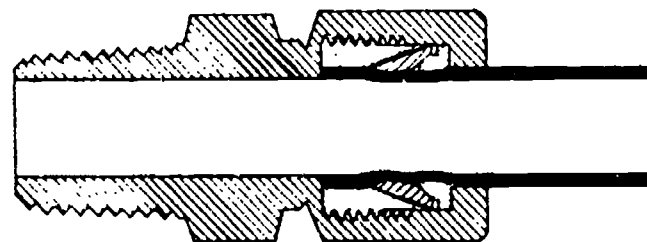
Flared



Bite Type Flareless

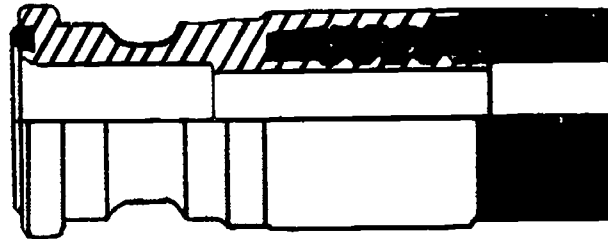


Braze-on

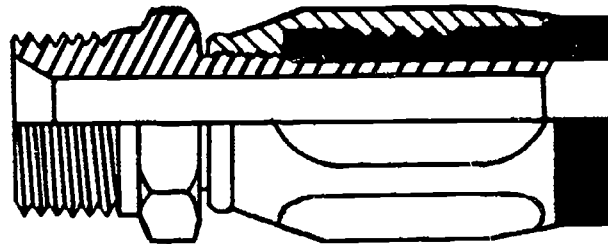


Swage Type Flareless

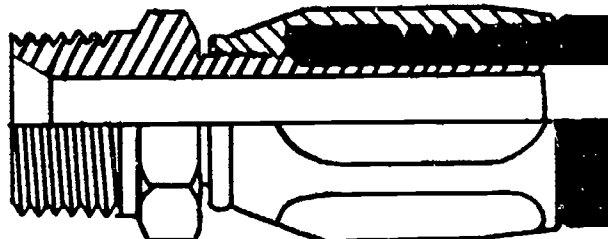
# Types of Hose Ends



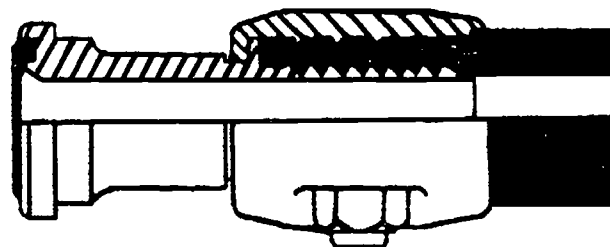
Permanent  
Hose Fitting



Skive Fitting



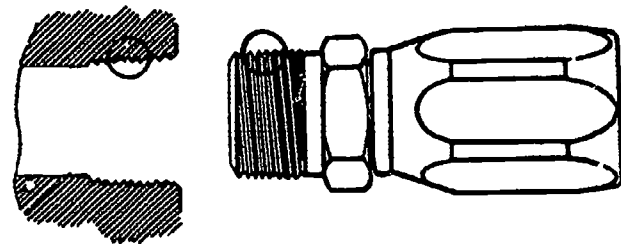
No-Skive Fitting



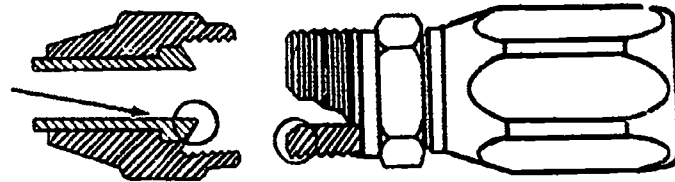
Clamp Type Fitting

# Types of Fittings Used in Hydraulic Systems

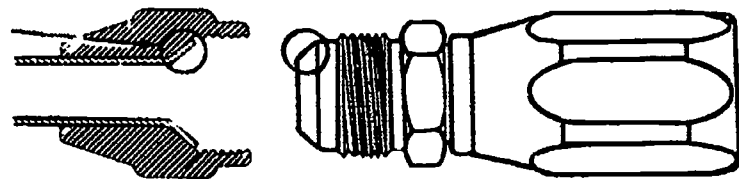
1. Pipe Thread  
(Tapered)



2. Dry Seal To  
30° Cone Seat  
(Inverted Flare)



3. Flare Seal  
To Cone Seat



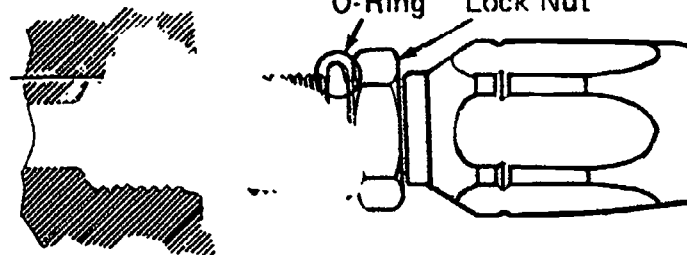
- J.I.C. Flare Seal to  
37° Cone Seat



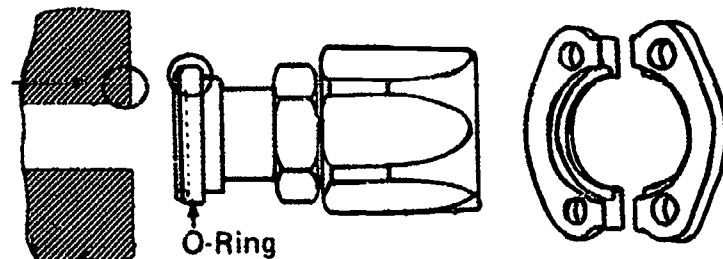
- S.A.E. Flare Seal to  
45° Cone Seat



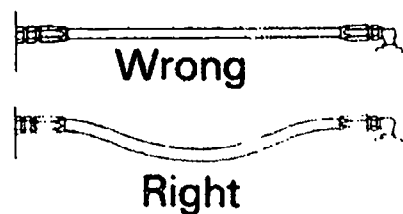
4. Straight Thread  
With O – Ring  
Seal



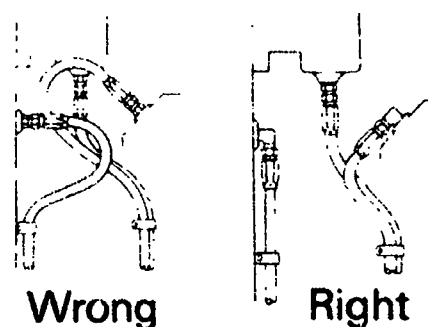
5. Split Flange  
O – Ring Seal



# Routing Hydraulic Hose and Tubing



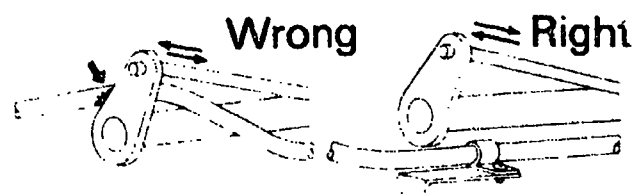
1. Avoid Taut Hose



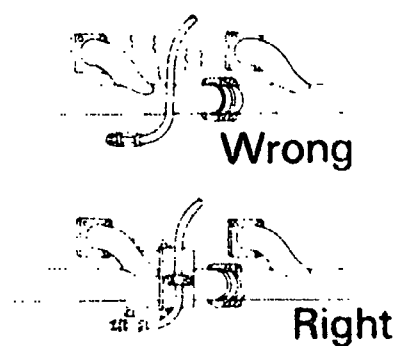
2. Avoid Loops



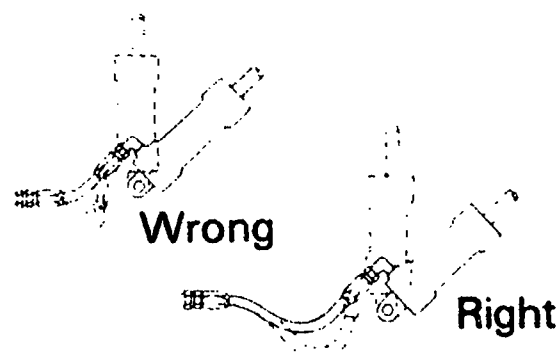
3. Avoid Twisting



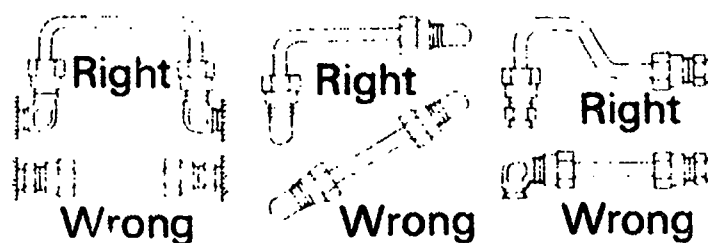
4. Avoid Rubbing



5. Avoid Heat



6. Avoid Sharp Bends



## **LINES, FITTINGS, AND COUPLERS UNIT IV**

### **JOB SHEET #1 — REPLACE A REUSABLE HOSE END**

#### **A. Tools and materials**

1. Wrenches as required
2. Hose with reusable hose ends
3. Replacement hose

(NOTE: Replacement hose must be matched to the hose ends.)

4. Tape measure
5. Tool to cut hose
6. Vise
7. Knife

#### **B. Procedure**

1. Remove the hose ends from the old hose

(NOTE: For clamp on hose ends the screw should be removed and the two halves of the clamp are to be removed. The hose-end nipple can then be removed. For skive and non-skive hose-ends the socket (sleeve) should be pulled off or unscrewed as appropriate. The hose-end nipple can then be removed.)

2. Measure replacement hose and cut to length
3. If the hose end is a skive type, use the knife to remove the outer covering where the sleeve is to be placed on the hose
4. Lubricate the end of the hose and place the sleeve on the hose
5. Place the sleeve and hose assembly into the vise
6. Insert the nipple and screw it into the sleeve and hose assembly until the nipple seats againsts the sleeve
7. Repeat for the other end

☐ Have your instructor check your work

8. Clean up area and return tools and materials to proper storage



# LINES, FITTINGS, AND COUPLERS

## UNIT IV

NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with the correct definitions.

- |         |   |                             |
|---------|---|-----------------------------|
| _____a. | Rigid fluid conductor which is not intended to be bent or shaped                              | 1. Fittings                 |
| _____b. | A semi-rigid fluid conductor which is customarily bent into a desired shape                   | 2. Pipe                     |
| _____c. | Flexible fluid conductor which can readily bend with movement of machine members              | 3. Skive                    |
| _____d. | A fitting which is attached onto a hose to allow the hose to be connected to other components | 4. Hose                     |
| _____e. | A device for connecting hydraulic components, such as a hose to a valve                       | 5. Joint Industrial Council |
| _____f. | An organization which is responsible for promotion of industrial standards                    | 6. Tubing                   |
| _____g. | To remove the outer covering on a hose  | 7. Hose end                 |

2. Select true statements concerning the characteristics of steel pipe by placing an "X" in the appropriate blanks.

- \_\_\_\_\_a. Size is typically specified by outside diameter
- \_\_\_\_\_b. Wall thickness is described by a schedule number
- \_\_\_\_\_c. Schedule 40 is commonly used for low pressure lines
- \_\_\_\_\_d. Schedule 160 is commonly used for very high pressure lines
- \_\_\_\_\_e. Schedule 80 is commonly used for low pressure lines

3. Discuss the characteristics of steel tubing.

a. Types

- 1) \_\_\_\_\_
- 2) \_\_\_\_\_

## TEST

b. Construction

- 1) \_\_\_\_\_
- 2) \_\_\_\_\_

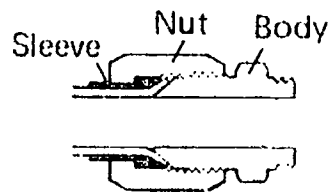
c. Size

- 1) \_\_\_\_\_
- 2) \_\_\_\_\_
  - a) \_\_\_\_\_
  - b) \_\_\_\_\_
  - c) \_\_\_\_\_

4. Select true statements concerning the characteristics of hydraulic hose by placing an "X" in the appropriate blanks.

- \_\_\_\_\_ a. The construction of hydraulic hose consists of an inner tube, reinforcement of wire or fiber braid, and cover
- \_\_\_\_\_ b. Factors to specify size include outside diameter, working pressure, and construction
- \_\_\_\_\_ c. Standard hose types were developed by the Society of Automotive Engineers (SAE)
- \_\_\_\_\_ d. Hoses are guaranteed by the manufacturer to meet a minimum safety standard

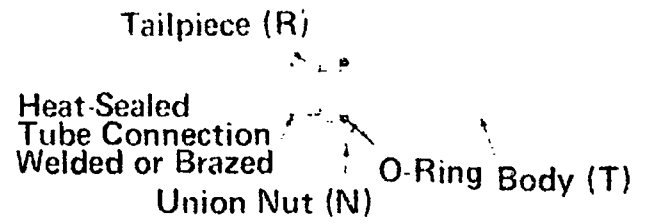
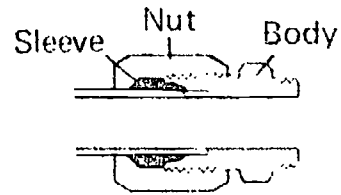
5. Identify the types of fittings commonly used with tubing.



a. \_\_\_\_\_

b. \_\_\_\_\_

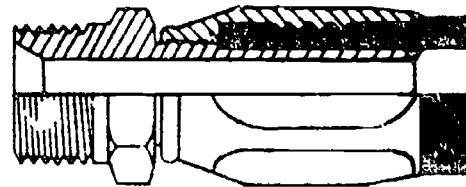
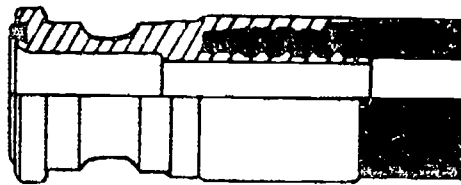
# TEST



c. \_\_\_\_\_

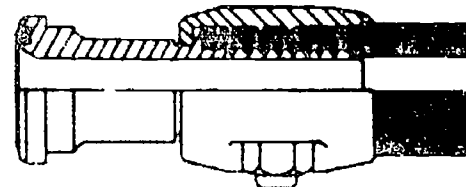
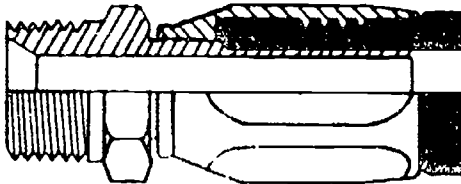
d. \_\_\_\_\_

6. Identify types of hose ends used in hydraulic systems.



a. \_\_\_\_\_

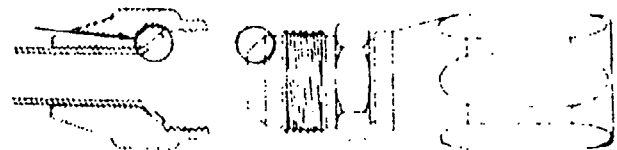
b. \_\_\_\_\_



c. \_\_\_\_\_

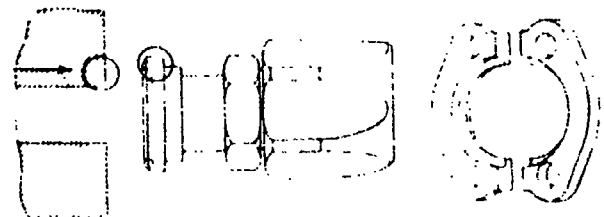
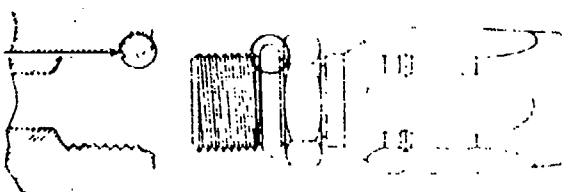
d. \_\_\_\_\_

7. Identify types of fittings used in hydraulic systems.



a. \_\_\_\_\_

b. \_\_\_\_\_



c. \_\_\_\_\_

d. \_\_\_\_\_

**TEST**

8. Select factors to consider when routing tubing in hydraulic systems by placing an "X" in the appropriate blanks.

- \_\_\_\_a. All hook-ups should be straight-line
- \_\_\_\_b. Use as many bends as possible
- \_\_\_\_c. Support long runs of tubing
- \_\_\_\_d. Avoid interference with operator controls

9. List five conditions to avoid when routing hydraulic hose.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

10. Demonstrate the ability to replace a reusable hose end.

## LINES, FITTINGS, AND COUPLERS UNIT IV

### ANSWERS TO TEST

1.   a.     2                   e.     1  
      b.     6                   f.     5  
      c.     4                   g.     3  
      d.     7
2.   b, c, d
3.   Discussion should include:
  - a.   Type
    - 1)   Stainless
    - 2)   Nonstainless
  - b.   Construction
    - 1)   Seamless
    - 2)   Welded
  - c.   Size
    - 1)   Indicated by outside diameter and wall thickness
    - 2)   Wall thickness sometimes described as:
      - a)   Thin wall
      - b)   Standard
      - c)   Thick wall
4.   a, c, d
5.   a.   Flare  
      b.   Swage type flareless  
      c.   Bite type flareless  
      d.   Braze-on
6.   a.   Permanent  
      b.   Skive reusable  
      c.   No-skive reusable  
      d.   Clamp-on reusable
7.   a.   Pipe thread  
      b.   Flare  
      c.   Straight thread  
      d.   Split flange
8.   c, d
9.   Any five of the following:
  - a.   Taut hose
  - b.   Loops
  - c.   Twists
  - d.   Rubbing
  - e.   Heat
  - f.   Sharp bends
10.   Performance skills evaluated to the satisfaction of the instructor

# **SEALS**

## **UNIT V**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to describe the leakage paths within a hydraulic system and match types of seals with their applications. The student should also be able to install an O-ring, a seal, and a packing. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student will be able to:

1. Match terms associated with seals with their correct definitions.
2. Describe two types of leakage paths in hydraulic systems.
3. Identify types of sealing devices used in hydraulic systems.
4. Match types of seals with their applications.
5. Identify types of seal construction.
6. Select factors to consider concerning seal material.
7. Demonstrate the ability to:
  - a. Install an O-ring. (Job Sheet #1)
  - b. Install a seal. (Job Sheet #2)
  - c. Install a packing. (Job Sheet #3)

## **SEALS UNIT V**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Use transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheets.
- G. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Typical Leakage Paths
  - 2. TM 2 — Types of Sealing Devices
  - 3. TM 3 — Types of Seal Construction
  - 4. TM 4 — Types of Seal Construction (Continued)
  - 5. TM 5 — Types of Seal Construction (Continued)
- D. Job sheets
  - 1. Job Sheet #1 — Install an O-ring
  - 2. Job Sheet #2 — Install a Seal
  - 3. Job Sheet #3 — Install a Packing
- E. Test
- F. Answers to test

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fluid Power I*. Cleveland, OH: Parker-Hannifin Corporation. 1979.
- B. *Fundamentals of Service*. Moline, IL: Deere and Company. 1967.
- C. *Industrial Hydraulics Manual*. Troy, MI: Sperry Rand Corporation. 1970.



## **SEALS UNIT V**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Sealing device — Any device which keeps hydraulic fluid from flowing between certain passages or keeps foreign material from entering the system
- B. Seal ring (seal) — A type of seal whose basic shape is a ring; may use various complex shapes to improve sealing characteristics
- C. O-ring — A simple seal with a round cross section
- D. Gasket — A thin flat seal sandwiched between two metal surfaces
- E. Packing — A seal with a square cross section or a seal with contoured layers for use with cylinder pistons
- F. Counter-bore — An enlarged area around a spool or shaft to allow room to accommodate a seal or O-ring
- G. Back-up ring — A ring installed behind an O-ring or seal to hold it in place
- H. Sealing compounds — Materials applied to machine surfaces to prevent leaks

#### **II. Types of leakage paths in hydraulic systems (Transparency 1)**

- A. Internal — Leakage from one compartment to another within a component
- B. External — Leakage from within the component to the outside

(NOTE: Although leakage is generally considered undesirable, some leakage may be designed into the component. For example, some pumps have internal leakage paths to help cool the pump. Also, some seals allow a small amount of leakage to lubricate the seal.)

#### **III. Types of sealing devices (Transparency 2)**

- A. Seal
- B. Packing
- C. O-ring
- D. Back-up ring
- E. Gasket

## INFORMATION SHEET

### F. Sealing compounds

1. Liquid sealing compounds
2. Plastic or Teflon tape

(CAUTION: Teflon tape subject to high temperatures can release dangerous toxic fumes.)

### IV. Types of seals and their applications

- A. Static — Used where no mechanical movement occurs
- B. Dynamic — Used where rotary or linear motion occurs
- C. Wiper seal — Used to prevent dirt from entering the system

(NOTE: Wiper seals "wipe" dirt from a cylinder rod.)

### V. Types of seal construction (Transparencies 3, 4, and 5)

- A. T-ring seal
- B. Lip seal
- C. Cup seal
- D. Face seal
- E. Piston ring seal

### VI. Factors to consider concerning seal material

- A. Compatibility with the hydraulic fluid
- B. Temperature extremes
- C. Exposure to environment
- D. Wear characteristics

(NOTE: Improper hydraulic fluid, excessive temperature extremes, and sunlight may cause seal material to become hard or spongy. These conditions may cause the seal to fail to perform as desired.)

# Typical Leakage Paths



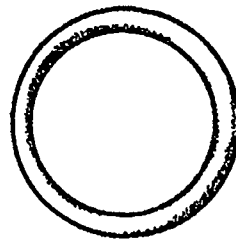
# Types of Sealing Devices

**Seal**

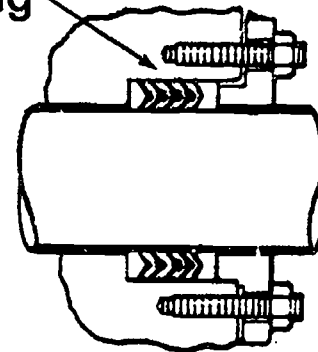


**Chevron or V-Shaped Packing**

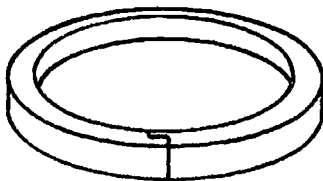
**Packing**



**O-Ring**

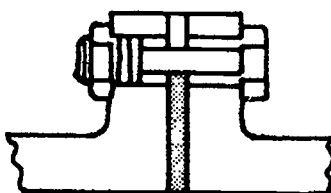


(Note: The Lip is Installed Towards Pressure.)

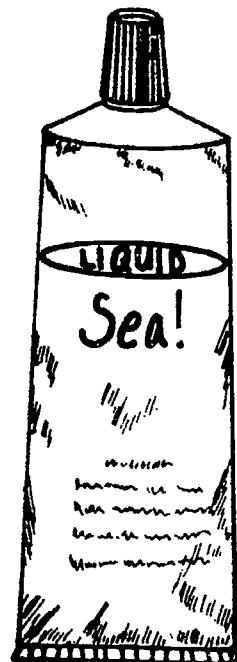


**Back-up Ring**

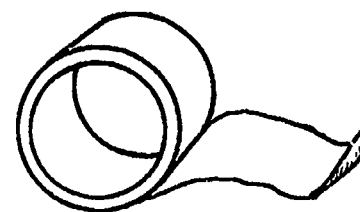
**Gasket**



**Sealing Compounds**



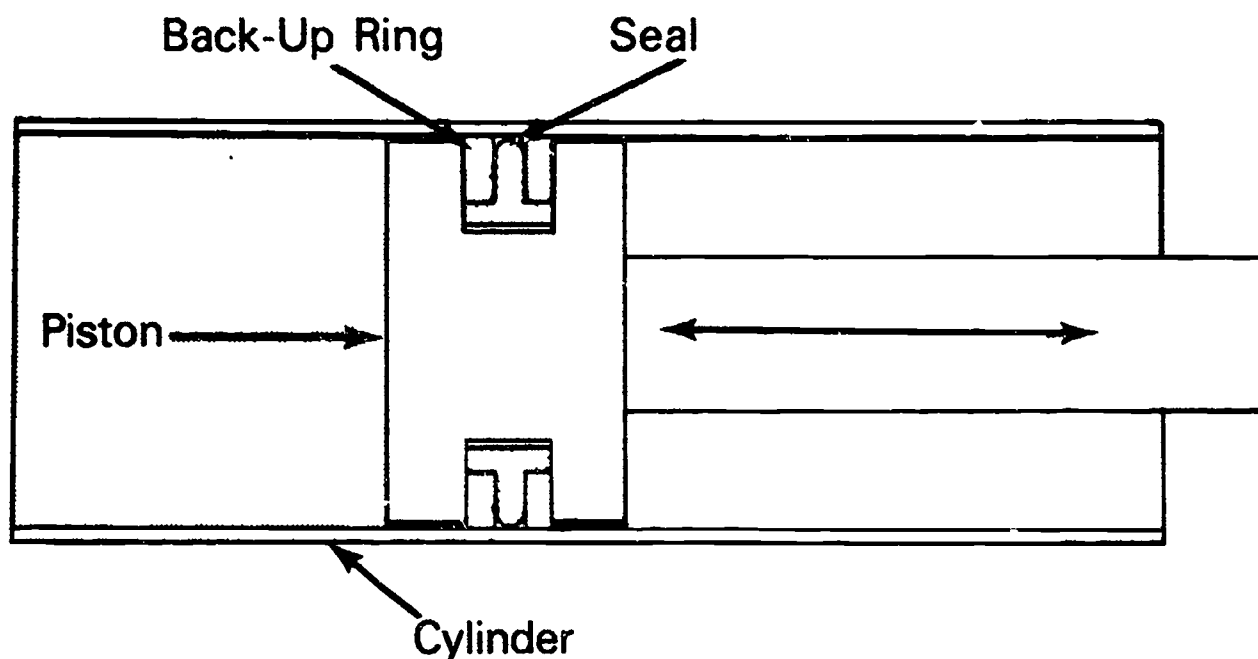
**Liquids**



**Plastic or Teflon Tape**

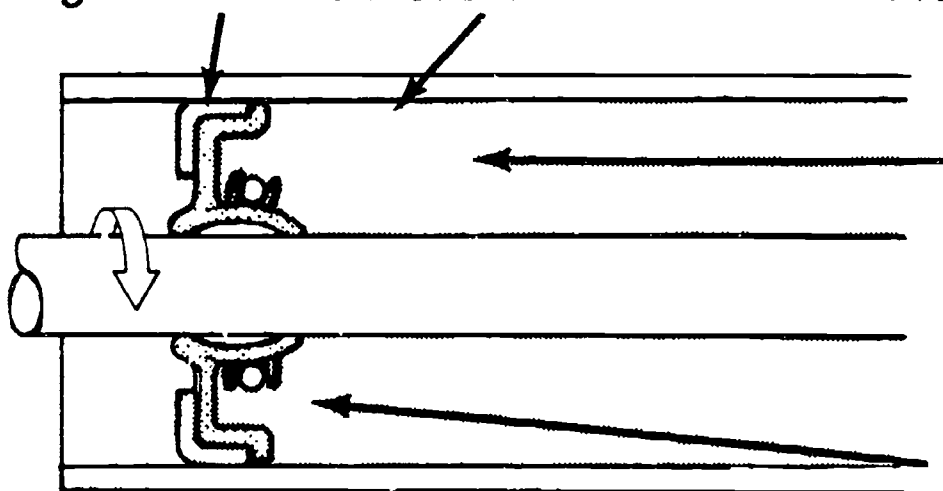
# Types of Seal Construction

## T-Ring Seal



A Stamped Housing Gives the Seal Rigidity and Facilitates Alignment at Installation.

The Lip is Formed of a Synthetic or Leather ; it is Installed Toward the Pressure Source.



Pressure Forces the Lip Tighter Around the Shaft to Aid Sealing.

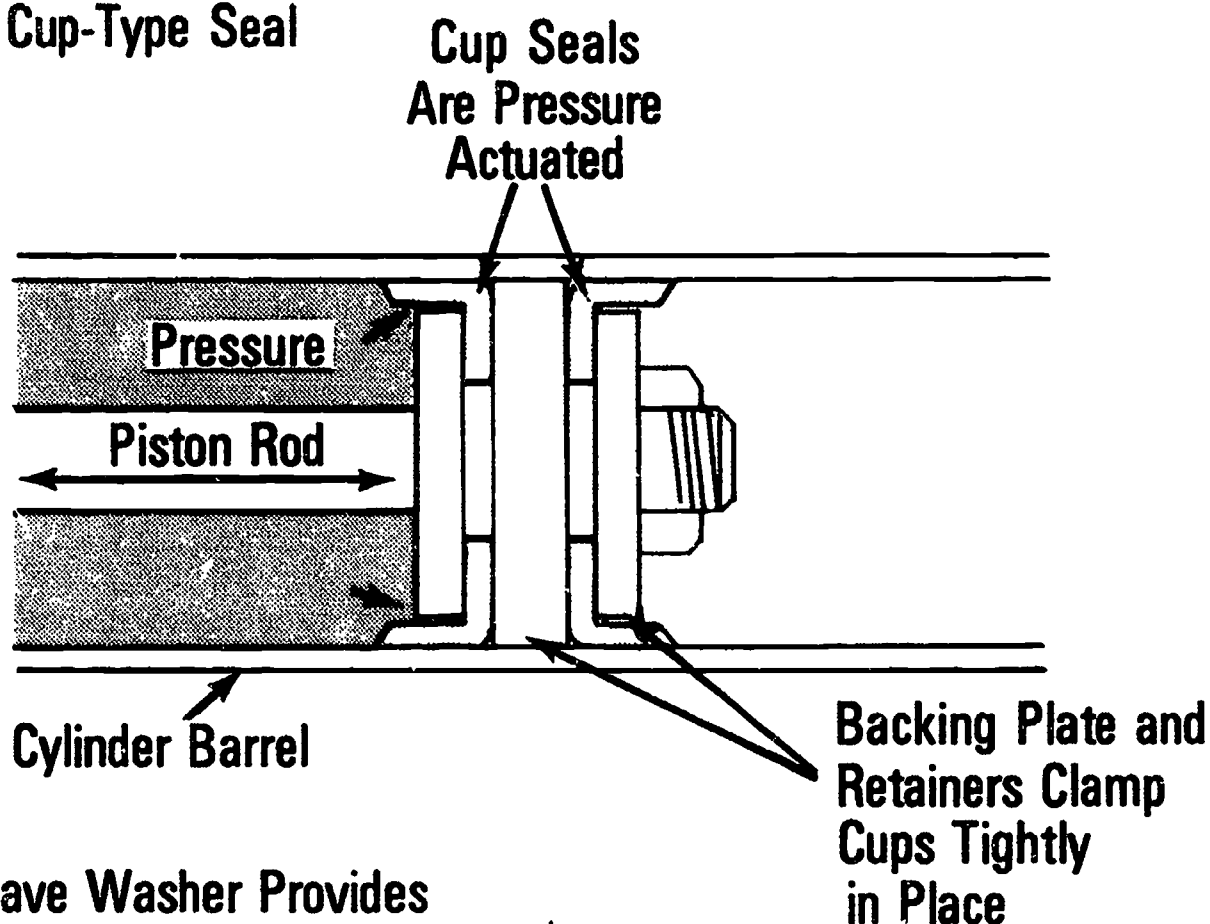
Spring Help Sealing When There is No Pressure

## Lip-Type Seal

# Types of Seal Construction

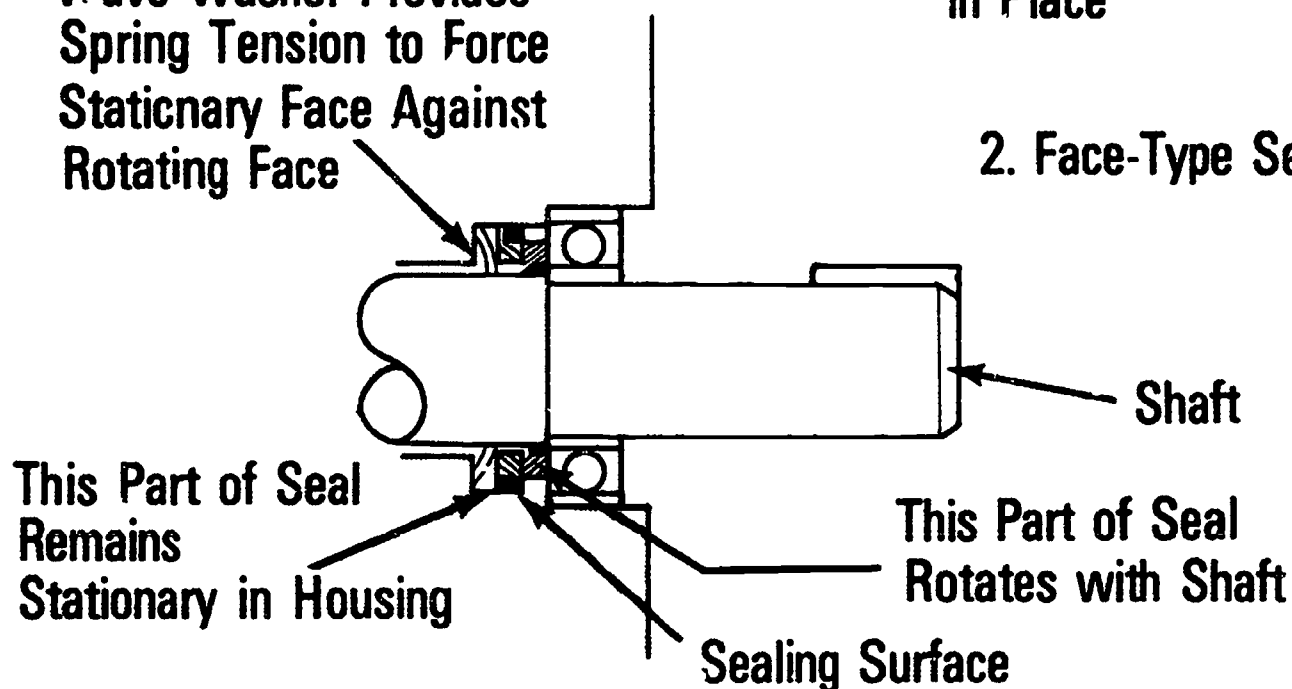
(Continued)

## 1. Cup-Type Seal



Wave Washer Provides Spring Tension to Force Stationary Face Against Rotating Face

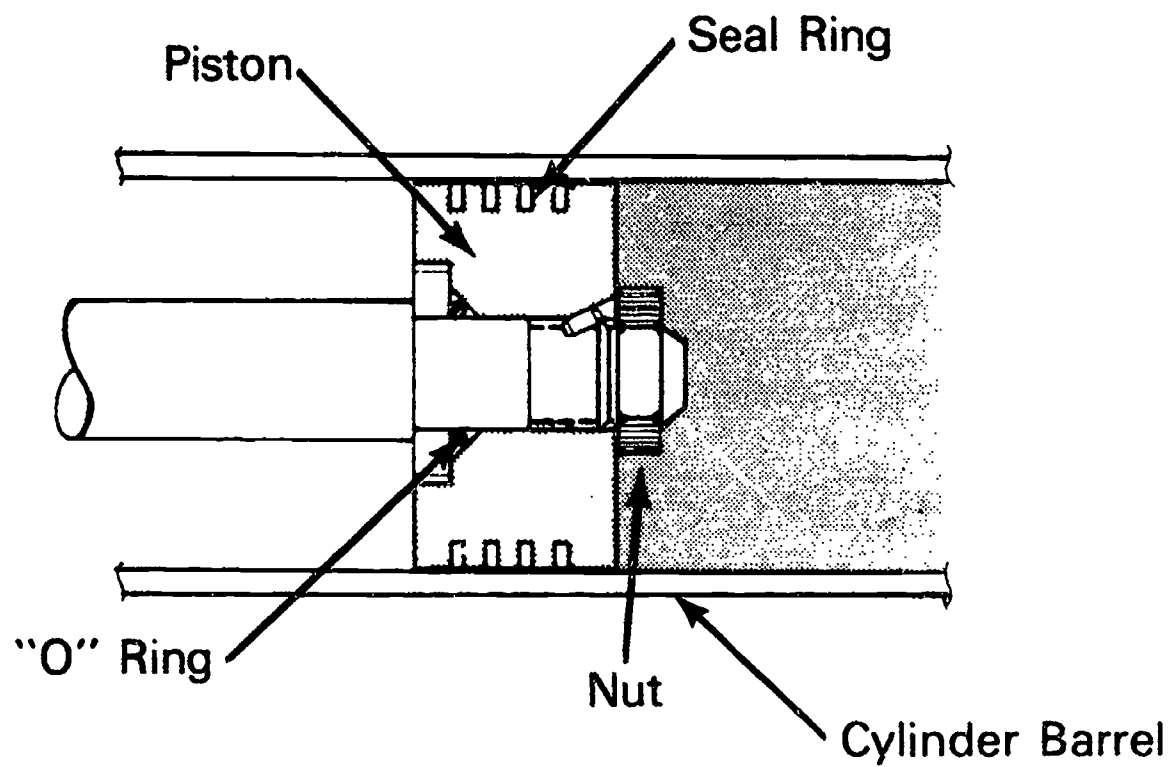
## 2. Face-Type Seal



# Types of Seal Construction

(Continued)

## Piston Ring Seal



## SEALS UNIT V

### JOB SHEET #1 — INSTALL AN O-RING

**A. Tools and materials**

1. Wrenches as required
2. O-ring remover tool
3. Fitting assembly which uses an O-ring seal  
(NOTE: Other components which use O-ring seals may be used.)
4. O-ring of appropriate size
5. Abrasive material such as emery cloth

**B. Procedure**

1. Clean dirt and other foreign material from assembly
2. Disassemble fitting (or other component) to have access to the O-ring
3. Remove old O-ring
4. inspect

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Inspect O-ring groove		
b. Remove sharp edges, nicks, or burrs with a fine abrasive stone  (NOTE: Extreme care should be taken with this operation.)		
c. Inspect shaft or spool for sharp edges		
d. Remove nicks or burrs with abrasive material		
e. Polish with a fine abrasive cloth		

5. Reclean assembly, removing any debris from above inspection



**JOB SHEET #1**

6. Install O-ring
  - a. Lube O-ring
  - b. Protect O-ring from sharp edges
  - c. If necessary, cover sharp edges with a thin plastic shim during installation  
(NOTE. Avoid twisting O-ring during installation.)

7. Reassemble
  - a. Align parts and reassemble
  - b. During reassembly, observe that the O-ring is properly seated and not cut or twisted

(NOTE: Only a slight squeeze should be applied to the O-ring. Normally, the component will be cycled for a few cycles and then visually inspected for leakage. This operation will not be performed at this time.)

☐ Have your instructor check your work

8. Clean up area and return tools and materials to proper storage

## SEALS UNIT V

### JOB SHEET #2 -- INSTALL A SEAL

**A. Tools and materials**

1. Wrenches as required
2. Seal installation tool (if required)
3. Cylinder which uses a wiper seal
4. Wiper seal
5. Abrasive material such as emery cloth

**B. Procedure**

(NOTE: This procedure may also be used for pressure type seals.)

1. Clean cylinder rod and end cap
2. Remove end cap
3. Remove old seal
4. Clean shaft and bore of cylinder
5. Inspect

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Check shaft for nicks and burrs		
b. Repair damaged area with abrasive material		
c. Polish with fine emery cloth		
d. Reclean		

6. Lubricate seal with recommended fluid to ease installation

**JOB SHEET #2**

7. Load seal onto shaft
  - a. Use plastic shim to protect seal from sharp edges
  - b. Insure that the seal is oriented properly
8. Coat outside diameter of metal cased seals with gasket cement to prevent leakage
9. Seat seal

(NOTE: Press-fit seals may require the use of a special tool to press the seal in place.)
10. Insure that the seal is securely installed
11. Reinstall end cap

(NOTE: Normally, the cylinder will be cycled for a few cycles then visually inspected for leakage. This operation will not be performed at this time.)
- ☐ Have your instructor check your work
12. Clean up area and return tools and materials to proper storage

## SEALS UNIT V

### JOB SHEET #3 --- INSTALL A PACKING

#### A. Tools and materials

1. Wrenches as required
2. Pump or other component which uses a seal
3. Packings
4. Abrasive material such as emery cloth

#### B. Procedure

1. Remove the gland or ring which retains the packs
2. Remove old packings
3. Inspect the shaft surface
4. Remove any nicks or scratches with the abrasive material
5. Soak the packing in hydraulic oil prior to installation
6. Install packings with the cup or V portion toward the pressure

(NOTE: Packs which are composed of individual rings should be installed with each rotated 180° from the last ring.)

7. Re-install the gland or retaining ring
8. Tighten only enough to prevent leakage

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

## SEALS UNIT V

NAME \_\_\_\_\_

### TEST

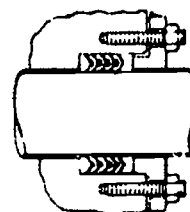
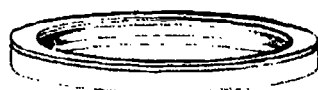
1. Match the terms on the right with the correct definitions.

- |         |   |                      |
|---------|---|----------------------|
| _____a. | Any device which keeps hydraulic fluid from flowing between certain passages or keeps foreign material from entering the system | 1. Gasket            |
| _____b. | A type of seal whose basic shape is a ring; may use various complex shapes to improve sealing characteristics                   | 2. Packing           |
| _____c. | A simple seal with a round cross section  | 3. Sealing device    |
| _____d. | A thin flat seal sandwiched between two metal surfaces  | 4. O-ring            |
| _____e. | A seal with a square cross section or a seal with contoured layers for use with cylinder pistons                                | 5. Seal ring         |
| _____f. | An enlarged area around a spool or shaft to allow room to accommodate a seal or O-ring  | 6. Counter-bore      |
| _____g. | A ring installed behind an O-ring or seal to hold it in place   | 7. Back-up ring      |
| _____h. | Materials applied to machine surfaces to prevent leaks  | 8. Sealing compounds |

2. Describe two types of leakage paths in hydraulic systems.

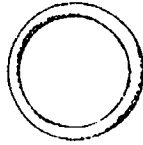
- a. Internal — \_\_\_\_\_
- b. External — \_\_\_\_\_

3. Identify types of sealing devices used in hydraulic systems.

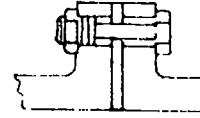


- a. \_\_\_\_\_
- b. \_\_\_\_\_

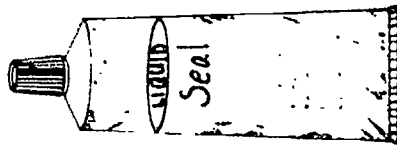
## TEST



c. \_\_\_\_\_



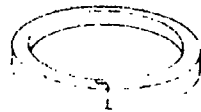
d. \_\_\_\_\_



e. \_\_\_\_\_



f. \_\_\_\_\_



g. \_\_\_\_\_

4. Match the types of seals on the right with their applications.

\_\_\_\_\_ a. Used to prevent dirt from entering the system

1. Static

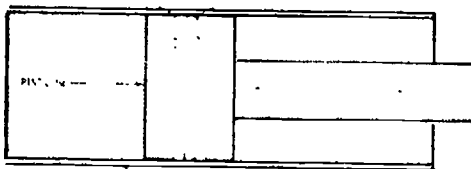
\_\_\_\_\_ b. Used where no mechanical movement occurs

2. Wiper seal

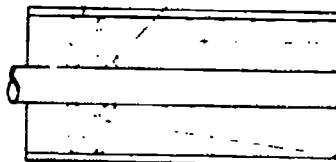
\_\_\_\_\_ c. Used where rotary or linear motion occurs

3. Dynamic

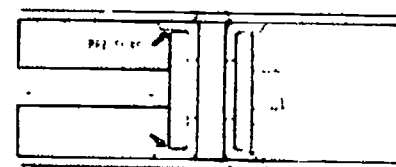
5. Identify types of seal construction.



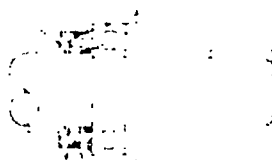
a. \_\_\_\_\_



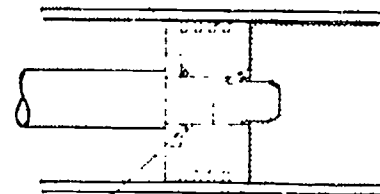
b. \_\_\_\_\_



c. \_\_\_\_\_



d. \_\_\_\_\_



e. \_\_\_\_\_

**TEST**

6. Select factors to consider concerning seal material by placing an "X" in the appropriate blanks.

- \_\_\_\_\_a. Temperature extremes
- \_\_\_\_\_b. Wear characteristics
- \_\_\_\_\_c. Noise conditions
- \_\_\_\_\_d. Dynamic elasticity
- \_\_\_\_\_e. Compatibility with the hydraulic fluid
- \_\_\_\_\_f. Exposure to environment
- \_\_\_\_\_g. Pressure of components

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

7. Demonstrate the ability to:

- a. Install an O-ring.
- b. Install a seal.
- c. Install a package.

## SEALS UNIT V

### ANSWERS TO TEST

1.   a.    3                   e.    2  
     b.    5                   f.    6  
     c.    4                   g.    7  
     d.    1                   h.    8
2.   Description should include:  
     a.    Leakage from one compartment to another within a component  
     b.    Leakage from within the component to the outside
3.   a.    Seal  
     b.    Packing  
     c.    O-ring  
     d.    Gasket  
     e.    Liquid sealing compound  
     f.    Plastic or Teflon  
     g.    Back-up ring
4.   a.    2  
     b.    1  
     c.    3
5.   a.    T-ring  
     b.    Lip seal  
     c.    Cup seal  
     d.    Face seal  
     e.    Piston ring seal
6.   a, b, e, f
7.   Performance skills evaluated to the satisfaction of the instructor



## **FLUIDS AND FILTERS**

### **UNIT VI**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to select the effects of contaminants and functions of filters in a hydraulic system and list functions of the fluid in a hydraulic system. The student should also be able to match the locations to the types of filters in the hydraulic system and identify types of filter circuits. This knowledge will be evidenced by scoring 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms associated with fluids and filters with their correct definitions.
2. Select the effects of contaminants in the hydraulic system.
3. List practices for assuring hydraulic system cleanliness.
4. Select functions of the filter in a hydraulic system.
5. Distinguish between surface filters and depth filters.
6. Match the locations with the types of filters in the hydraulic system.
7. Identify types of filter circuits.
8. Select factors used in specifying a filter.
9. Draw the symbol for a filter.
10. List four functions of the fluid in hydraulic systems.
11. Select true statements concerning the effect of temperature on the viscosity of hydraulic fluids.
12. Name common additives in hydraulic systems.
13. List six safety rules to remember when working with hydraulic fluid.

## **FLUIDS AND FILTERS UNIT VI**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information sheet.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Show students types of filters.
- G. Disassemble filter to show functions of filters.
- H. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Types of Filters
  - 2. TM 2 — Locations of Filters in Hydraulic System
  - 3. TM 3 — Types of Filter Circuits
- D. Test
- E. Answers to test

### **REFERENCES USED IN DEVELOPING THIS UNIT**

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: John Deere and Company, 1967.
- B. Pippinger, John, and Tyler Hicks. *Industrial Hydraulics*. New York: McGraw-Hill Book Company, 1979
- C. *Fluid Power Designer's Lightning Reference Handbook*. Orange, CA: Paul-Munroe Hydraulics, Inc., 1976.

## **FLUIDS AND FILTERS UNIT VI**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Contaminant — Any unwanted material in the hydraulic system

(NOTE: This includes various chemicals and particles such as metal, rust, sand, and water which is the most common frequent contaminant.)

- B. Particulate contaminant — Contaminants which is composed of particles

- C. Filter — A device which removes contaminants from hydraulic systems

- D. Strainer — A very coarse filter typically used to prevent large items such as rocks and bolts from entering the system

- E. Viscosity — A measure of the fluid's resistance to flow

(NOTE: The viscosity will vary as temperature varies.)

- F. Micron — A measure of size equal to one millionth of a meter

(NOTE: Micron size is often used to describe the size of particles which a filter will remove from the fluid. For example, a 10 micron absolute filter is designed to remove all particles greater than 10 microns.)

#### **II. Effects of contaminants in the hydraulic system**

(NOTE: One teaspoon of dust in 55 gallons of oil constitutes a dirty system.)

- A. Reduced component life

(NOTE: Even small amounts of contaminant in the system may wear out a hydraulic pump in as little as a few hours.)

- B. Scored internal surfaces

(NOTE: Scored internal surfaces can result in excess leakage and poor performance.)

- C. Clogged internal passages

- D. Seized components

- E. Poor performance

- F. Improper operation

## INFORMATION SHEET

### III. Practices for assuring hydraulic system cleanliness

- A. Change fluid and filter regularly
- B. Fill system only with clean oil  
(NOTE: Factory fresh oil is often quite dirty.)
- C. Clean dirt off breather caps and filler plugs prior to opening system
- D. Use a clean, lint-free towel to wipe dipstick
- E. Replace worn seals  
(NOTE: Worn wiper seals on cylinders can allow a large amount of dirt to enter the system through the cylinder.)
- F. Keep work area clean  
(NOTE: This is especially important when disassembling components such as pumps.)
- G. Clean and flush components prior to installing in system

### IV. Functions of the filter in a hydraulic system

- A. To remove dirt that has entered the system: through breather caps, seals, open lines, and unclean components
- B. To remove metal particles generated by wear processes
- C. To remove particles resulting from rust or corrosion of internal surfaces

### V. Types of filters (Transparency 1)

- A. Surface filter — Has a single surface that catches and removes dirt particles larger than the holes in the filter
- B. Depth filter — Uses a large volume of filter material to trap the particles as the oil passes through  
(NOTE: This filter material is similar to cotton.)

### VI. Locations of filters in the hydraulic system (Transparency 2)

- A. Strainer or suction line filter — Inlet of the pump  
(NOTE: An inlet strainer is used only to prevent objects such as nuts, bolts, and metal chips from entering the pump.)
- B. Pressure line filter — Outlet of the pump
- C. Return line filter — Return line between outlet of load and reservoir

## INFORMATION SHEET

### VII. Types of filter circuits (Transparency 3)

- A. Full flow filter
- B. Partial flow filter
- C. Auxiliary flow filter

### VIII. Factors used in specifying a filter

- A. Degree of filtration (performance)

(NOTE: This is commonly expressed as an efficiency or as minimum size particle removed.)

- B. Flow rate
- C. Pressure drop
- D. Dirt capacity
- E. System pressure
- F. Operating temperature

### IX. Symbol for a filter



(NOTE: This symbol is also used for a strainer.)

### X. Functions of the fluid in hydraulic systems

- A. Transmit power
- B. Lubricate system
- C. Assist in sealing system
- D. Transport heat

### XI. Effect of temperature on the viscosity of hydraulic fluids

- A. Viscosity will decrease as temperature increases
- B. Viscosity will increase as temperature decreases
- C. The amount of change in viscosity for a specified change in temperature is known as the viscosity index
- D. Some new hydraulics fluids are multi-viscosity and function well in almost all temperature ranges

## INFORMATION SHEET

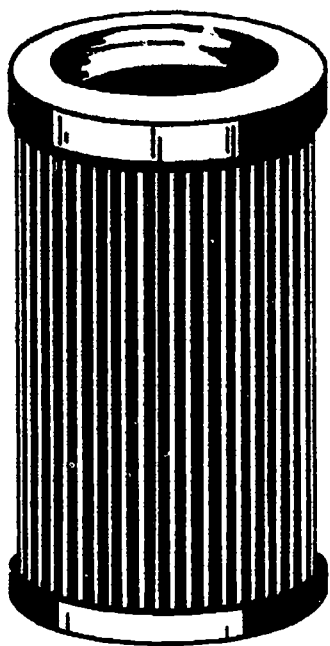
### **XII. Common additives in hydraulic systems**

- A. Viscosity index improver to keep oil at a consistent viscosity in extremes of heat and cold
- B. Anti-wear additives
- C. Anti-oxidation compounds
- D. Corrosion inhibitors
- E. Anti-foam additives

### **XIII. Safety rules to remember when working with hydraulic fluids**

- A. Allow the system to cool prior to working on it  
  
(NOTE: Fluid in a working hydraulic system will commonly be in the temperature range of 150°F to 225°F or even higher. These temperatures can cause severe burns.)
- B. Avoid contact with skin and eyes  
  
(NOTE: Some hydraulic fluids are very caustic, particularly aircraft fluids.)
- C. Remove filter cap slowly to relieve any trapped pressure  
  
(NOTE: Some systems are capable of pressure build up in the reservoir from thermal expansion of the fluid caused by a hot day. It is possible that you may be sprayed with oil if the pressure is not slowly released.)
- D. Since many hydraulic fluids are flammable, treat all fluids as flammable materials  
  
(NOTE: Most hydraulic fluids used on mobile equipment are flammable.)
- E. Avoid contact with hot objects such as exhaust manifolds
- F. Wear safety glasses when entering a hydraulic system at any point

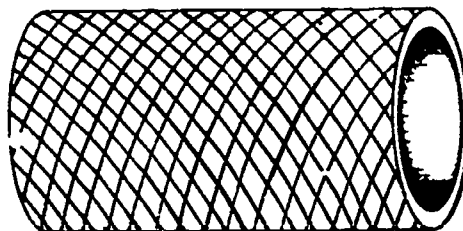
# Types of Filters



**Surface Filter**  
**(Wire Mesh Filter)**

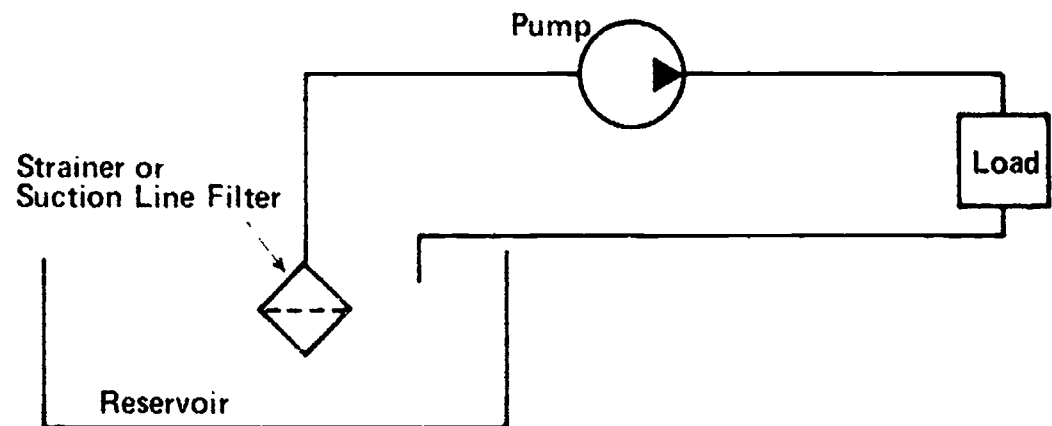


**Depth Filter**  
**(Cotton Waste Filter)**

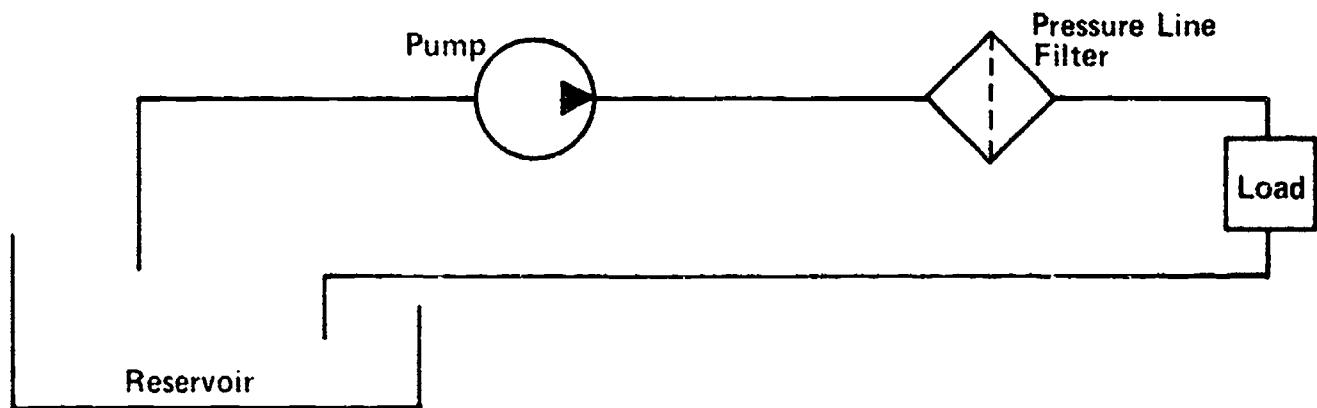


**Strainer Filter**

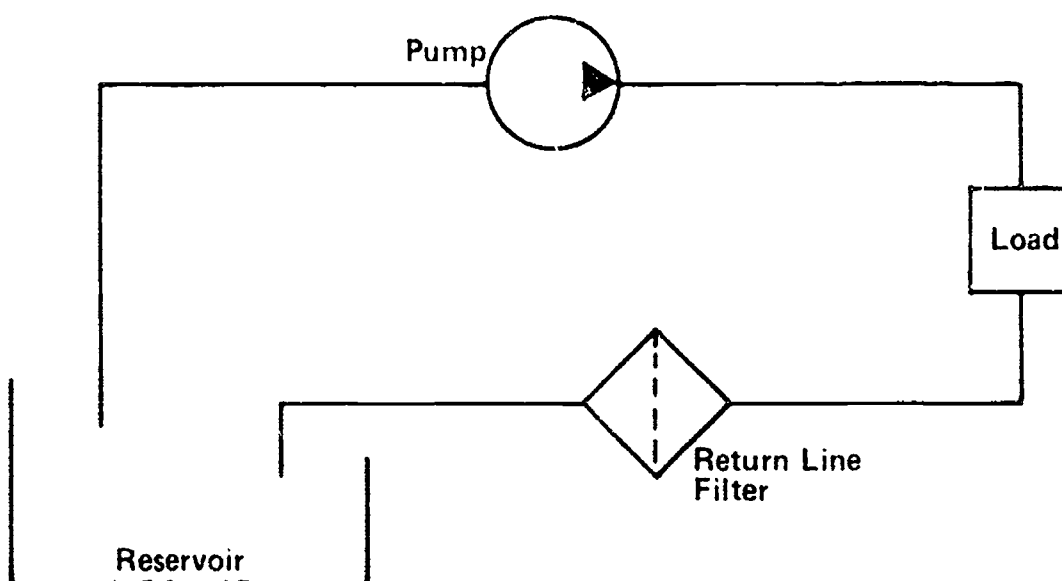
# Location of Filters in Hydraulic System



**Strainer or Suction Line Filter**



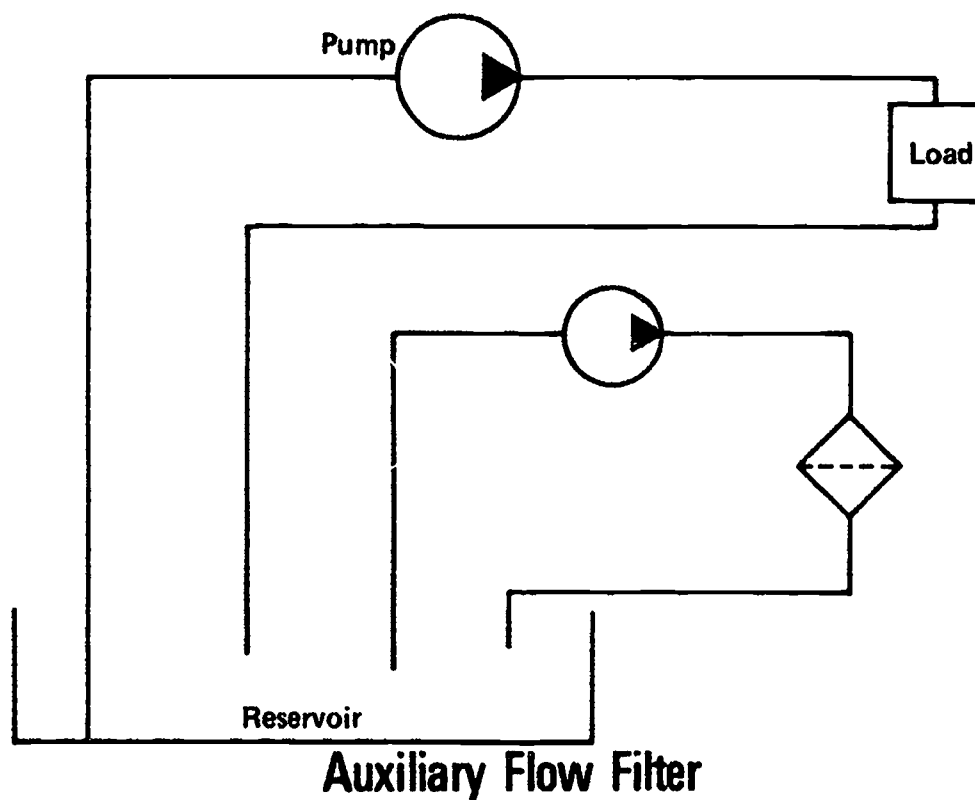
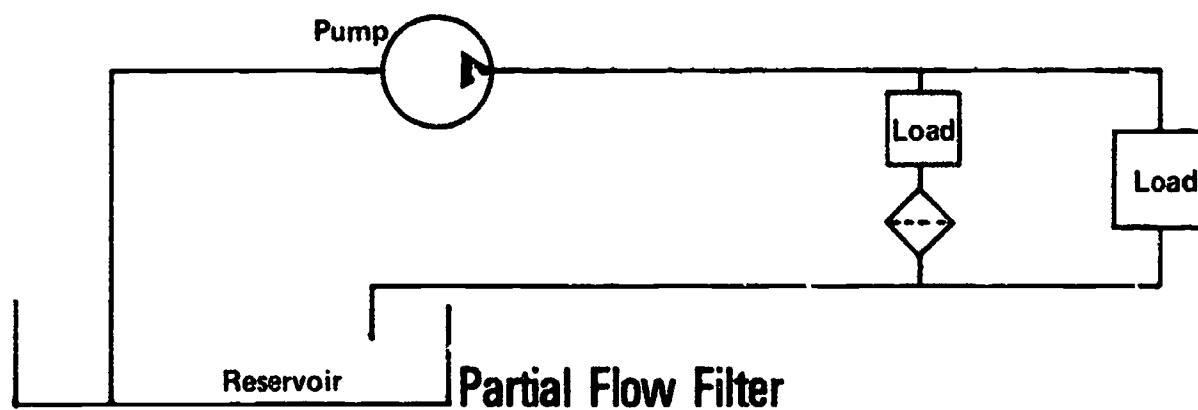
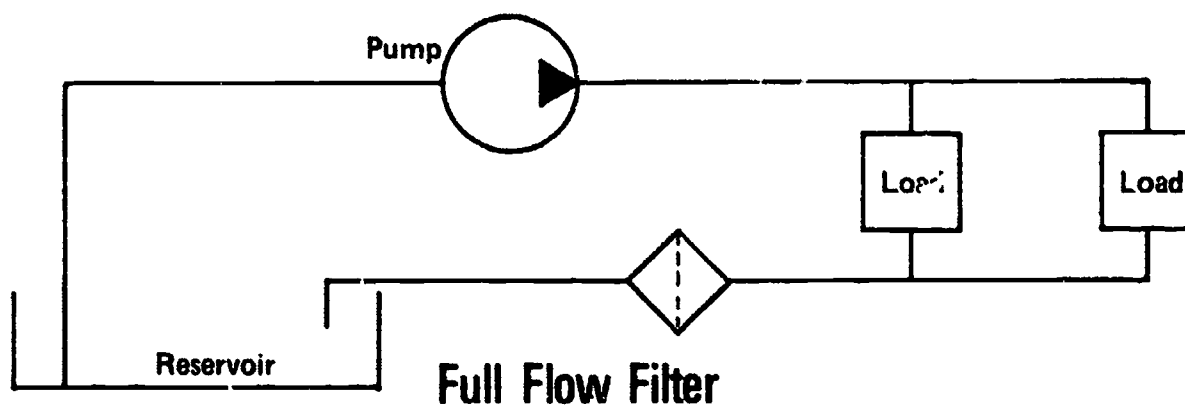
**Pressure Line Filter**



**Return Line Filter**



# Types of Filter Circuits



## FLUIDS AND FILTERS UNIT VI

NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with the correct definitions.

_____a.	Any unwanted material in the hydraulic system	1. Strainer
_____b.	Contaminant which is composed of particles	2. Contaminant
_____c.	A device which removes contaminants from hydraulic systems	3. Viscosity
_____d.	A very coarse filter typically used to prevent large items such as rocks and bolts from entering the system	4. Filter
_____e.	A measure of the fluid's resistance to flow	5. Micron
_____f.	A measure of size equal to one millionth of a meter	6. Particulate contaminant

2. Select the effects of contaminants in the hydraulic system by placing an "X" in the appropriate blanks.

_____a.	Clogged internal passages
_____b.	Better performance
_____c.	Smooth internal surfaces
_____d.	Improper operation
_____e.	Reduced component life
_____f.	Better availability of parts
_____g.	Scored internal surfaces
_____h.	Seized components

## TEST

3. List five practices for assuring hydraulic system cleanliness.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

4. Select functions of the filter in a hydraulic system by placing an "X" in the appropriate blanks.

- \_\_\_\_\_a. To remove rocks and bolts in the hydraulic fluid
- \_\_\_\_\_b. To remove particles resulting from rust or corrosion of internal surfaces
- \_\_\_\_\_c. To remove water in the oil
- \_\_\_\_\_d. To remove metal particles generated by wear processes
- \_\_\_\_\_e. To remove dirt that has entered the system through breather caps, seals, open lines, and unclean components

5. Distinguish between surface filters and depth filters by placing an "X" next to the description of depth filters.

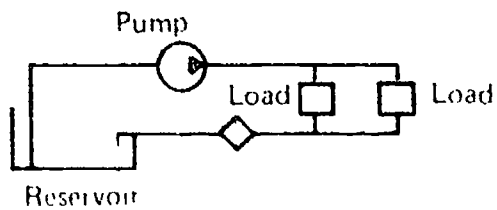
- \_\_\_\_\_a. Has a single surface that catches and removes dirt particles larger than the holes in the filter
- \_\_\_\_\_b. Uses a large volume of filter material to trap the particles as the oil passes through

6. Match the locations of filters in the hydraulic system with the correct filters.

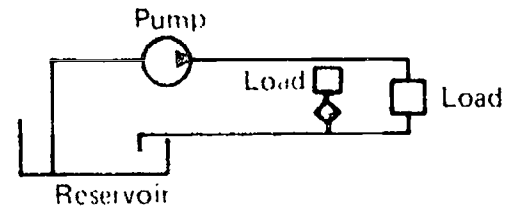
- |   |   |
|---|---|
| _____a. Pressure line filter            | 1. Inlet of the pump                                |
| _____b. Return line filter              | 2. Outlet of the pump                               |
| _____c. Strainer or suction line filter | 3. Return line between outlet of load and reservoir |

## TEST

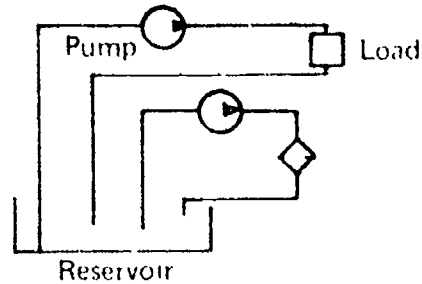
7. Identify types of filter circuits.



a. \_\_\_\_\_



b. \_\_\_\_\_



c. \_\_\_\_\_

8. Select factors used in specifying a filter by placing an "X" in the appropriate blanks.

- \_\_\_\_ a. Degree of filtration
- \_\_\_\_ b. Flow rate
- \_\_\_\_ c. Water pressure
- \_\_\_\_ d. Dirt capacity
- \_\_\_\_ e. Pressure drop
- \_\_\_\_ f. Size of hydraulic lines
- \_\_\_\_ g. System pressure
- \_\_\_\_ h. Amount of water in the oil
- \_\_\_\_ i. Operating temperature


9. Draw the symbol for a filter.

**TEST**

10. List four functions of the fluid in hydraulic systems.
- a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
  - d. \_\_\_\_\_
11. Select true statements concerning the effect of temperature on the viscosity of hydraulic fluids by placing an "X" in the appropriate blanks.
- \_\_\_\_\_a. Viscosity will decrease as temperature increases
  - \_\_\_\_\_b. Viscosity will increase as temperature increases
  - \_\_\_\_\_c. Viscosity will decrease as temperature decreases
  - \_\_\_\_\_d. Viscosity will increase as temperature decreases
  - \_\_\_\_\_e. The amount of change in viscosity for a specified change in temperature is known as the viscosity index
  - \_\_\_\_\_f. Some new hydraulic fluids are multi-viscosity and function well in almost all temperature ranges
12. Name three common additives in hydraulic systems.
- a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
13. List six safety rules to remember when working with hydraulic fluids.
- a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
  - d. \_\_\_\_\_
  - e. \_\_\_\_\_
  - f. \_\_\_\_\_

## FLUIDS AND FILTERS UNIT VI

### ANSWERS TO TEST

1.   a.    2                   d.    1  
     b.    6                   e.    3  
     c.    4                   f.    5
  
2.   a. d, e, g, h
  
3.   Any five of the following:
  - a.    Change fluid and filter regularly
  - b.    Fill system only with clean oil
  - c.    Clean dirt off breather caps and filler plugs prior to opening system
  - d.    Use a clean, lint-free towel to wipe dipstick
  - e.    Replace worn seals
  - f.    Keep work area clean
  - g.    Clean and flush components prior to installing in system
  
4.   b, d, e
  
5.   b
  
6.   a.    2  
     b.    3  
     c.    1
  
7.   a.    Full flow filter  
     b.    Partial flow filter  
     c.    Auxiliary flow filter
  
8.   a, b, d, e, g, i
  
9.   
  
10.   a.    Transmit power  
     b.    Lubricate system  
     c.    Assist in sealing system  
     d.    Transport heat
  
11.   a, d, e, f

**ANSWERS TO TEST**

12. Any three of the following:
  - a. Viscosity index improver
  - b. Anti-wear additives
  - c. Anti-oxidation compounds
  - d. Corrosion inhibitors
  - e. Anti-foam additives
13.
  - a. Allow the system to cool prior to working on it
  - b. Avoid contact with skin and eyes
  - c. Remove filter cap slowly to relieve any trapped pressure
  - d. Since many hydraulic fluids are flammable, treat all fluids as flammable material
  - e. Avoid contact with hot objects such as exhaust manifolds
  - f. Wear safety glasses when entering a hydraulic system at any point

## **PUMPS UNIT VII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to calculate pump displacement, flow rate, input and output power, and pump volumetric efficiency. The student should also be able to discuss the operation of a gear pump, and axial piston pump, and select true statements concerning the operation of vane pumps. The student should also be able to disassemble, inspect, and reassemble a gear pump and a pressure compensated pump. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment and job sheets and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to pumps with their correct definitions.
2. Distinguish between positive and nonpositive displacement pumps.
3. Name kinds of positive displacement pumps.
4. Given the formula, calculate pump displacement.
5. Given the formula, calculate pump flow rate.
6. Given the formulas, calculate pump input and output power.
7. Calculate pump volumetric efficiency.
8. Discuss the operation of a gear pump.
9. Select true statements concerning the operation of vane pumps.
10. Distinguish between an axial and a radial piston pump.
11. Select true statements concerning the operation of a radial piston pump.
12. Name two types of axial piston pumps.
13. Discuss the construction and operation of axial piston pumps.



## OBJECTIVE SHEET

14. Select true statements concerning the operation of a variable displacement axial piston pump.
15. Identify the parts of a servo-controlled variable displacement pump.
16. Match the components of pressure compensated axial piston pumps with their functions.
17. List four causes of hydraulic pump cavitation.
18. List common causes of hydraulic pump failure.
19. Draw the symbols for types of pumps.
20. Demonstrate the ability to:
  - a. Disassemble, inspect, and reassemble a gear pump. (Job Sheet #1)
  - b. Disassemble, inspect, and reassemble a pressure compensated variable displacement pump. (Job Sheet #2)

## **PUMPS UNIT VII**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information, assignment, and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the assignment and job sheets.
- G. Show students different types of pumps and demonstrate their operation.
- H. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Gear Pump
  - 2. TM 2 — Vane Pumps
  - 3. TM 3 — Types of Piston Pumps
  - 4. TM 4 — Construction and Operation of Axial Piston Pumps
  - 5. TM 5 — Bent-Axis Axial Piston Pump — Fixed Displacement
  - 6. TM 6 — Operation of Variable Displacement Axial Piston Pump
  - 7. TM 7 — Parts of a Servo-Controlled Variable Displacement Pump
  - 8. TM 8 — Operation of Pressure Compensated Axial Piston Pumps
- D. Assignment Sheet #1 — Calculate Pump Displacement, Flow Rate, Input and Output Power, and Overall Efficiency
- E. Answers to assignment sheet

## CONTENTS OF THIS UNIT

- F. Job sheets
  - 1. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Gear Pump
  - 2. Job Sheet #2 — Disassemble, Inspect, and Reassemble a Pressure Compensated Variable Displacement Pump
- G. Test
- H. Answers to test

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: John Deere and Company, 1967.
- B. *Industrial Hydraulics Manual* 935100-A. Troy, MI: Sperry-Rand Corporations, 1970.
- C. *Fluid Power 1*. Cleveland, OH 44112: Parker-Hannifin Corporation, 1975.

# **PUMPS**

## **UNIT VII**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Pump — A device which creates the flow of fluid
- B. Displacement — The volume of fluid which is transferred from the pump inlet to the outlet during one revolution of the pump
- C. Volumetric efficiency — The actual flow rate from a pump divided by the theoretical flow rate

(NOTE: The theoretical flow rate is calculated using  $Q = n \times d / 231$  where Q is the theoretical flow rate, n is the speed in revolutions per minute, and d is the displacement in cubic inches. Efficiency is often expressed as a percentage.)

- D. Cavitation — The formation of air bubbles in the inlet of a pump because the inlet does not completely fill with fluid
- E. Aeration — Air in the fluid
- F. Back pressure — Pressure in the return line caused by flow through the line from the pump to the reservoir

#### **II. Types of pumps**

- A. Positive displacement — A pump whose inlet is sealed from the outlet; will deliver fluid any time the inlet is kept supplied and the pump is driven
- B. Nonpositive displacement — A pump whose inlet and outlet are hydraulically connected so that the fluid can recirculate in the pump when pressure builds up

#### **III. Kinds of positive displacement pumps**

- A. Gear
- B. Vane
- C. Piston
- D. Screw

## INFORMATION SHEET

### IV. Formula for calculation of pump displacement

$$d = \frac{231Q}{n}$$

where  $d$  = displacement in in /revolution

$Q$  = pump outlet flow rate in gallons per minute (GPM)

$n$  = pump speed in revolutions per minute (RPM)

Example: A pump which has an outlet flow of 20 GPM at 1800 RPM has a displacement of 2.56 in/rev

$$d = \frac{231 \times 20 \text{ GPM}}{1800 \text{ RPM}} = 2.56 \text{ in/rev}$$

### V. Formula for calculation of pump flow rate

$$Q = \frac{n \times d}{231}$$

Example: A 2.56 in /rev. pump operating at 2400 RPM has a flow rate of 26.6 GPM

$$Q = \frac{2400 \times 2.56}{231} = 26.6 \text{ GPM}$$

### VI. Formula for calculation of pump power

#### A. Output power

$$\text{Power} = \frac{P \times Q}{1714}$$

where Power = Output power in horsepower

$P$  = Outlet pressure in PSI

$Q$  = Outlet flow in GPM

Example: A pump operating with 20 GPM flow and 3000 PSI outlet pressure has output power of 35 HP

$$\text{Power} = \frac{3000 \text{ PSI} \times 20 \text{ GPM}}{1714} = 35 \text{ HP}$$

## INFORMATION SHEET

### B. Input power

$$\text{Power} = \frac{n \times \text{Torque}}{5252}$$

where Power = Input power in horsepower  
 Torque = Input shaft torque in ft./lbs.  
 n = Speed in RPM

Example: A pump operating at 2400 RPM with a shaft torque of 70 ft. lbs. has input power of 32 HP

$$\text{Power} = \frac{(2400\text{RPM})(70 \text{ ft. lbs.})}{5252} = 32 \text{ HP}$$

### VII. Formula for calculation of volumetric efficiency

$$\text{Volumetric Eff} = \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}}$$

Example: The outlet flow rate of 2.56 in<sup>3</sup>/rev. pump operating at 2400 rpm is measured to be 22.5 gallons per minute (GPM). The volumetric efficiency is 84.4%.

Theoretical flow rate =

$$\frac{n \times d}{231} = \frac{2400 \text{ RPM} \times 2.56 \text{ in}^3}{231} / \text{rev} = 26.6 \text{ GPM}$$

$$\text{Volumetric Eff} = \frac{22.5 \text{ GPM}}{26.6 \text{ GPM}} = 0.844$$

### VIII. Operation of a gear pump (Transparency 1)

- A. The gear pump consists of two or more gears
  1. Drive gear — Power from engine or motor is applied to this gear
  2. Driven gear — Rotation of driver gear also causes rotation of driven gear
- B. As the gears pass the inlet of the pump, the space between the gear teeth fills with fluid
- C. The rotation of the gears carries the fluid around the outside perimeter of the gears to the outlet

## INFORMATION SHEET

### IX. Construction and operation of vane pumps (Transparency 2)

#### A. Fixed displacement

1. A fixed displacement vane pump consists of a slotted rotor inside a circular chamber
2. The chamber has inlet and outlet ports for supplying low pressure fluid and expelling pressurized fluid
3. Vanes are installed into the slots in the rotor and are free to move in a radial direction (that is, towards or away from the center of the rotor)
4. As the rotor rotates, the vanes are forced outward to contact the surface of the circular chamber
5. The rotor is installed offset (not in the center) in the circular chamber
6. As the rotor rotates a vane past the inlet port, a volume of fluid is trapped between two vanes
7. Because the rotor is installed offset in the circular chamber, the volume contained between two rotors becomes smaller and the trapped fluid is expelled from the outlet

(NOTE: This is the operation of an unbalanced vane pump. A balanced vane pump is similar except it has two inlets and two outlets.)

- #### B. Variable displacement — The displacement of a vane pump can be changed by changing the position of the rotor in the circular chamber

(NOTE: Only unbalanced vane pumps may be used as variable displacement pumps.)

### X. Types of piston pumps (Transparency 3)

- A. Axial — Pistons are parallel to the axis of the pump
- B. Radial — Pistons are perpendicular to the axis of the pump

### XI. Operation of a radial piston pump (Transparency 3)

- A. Pistons are installed radially to the pump, or perpendicular to the shaft
- B. The pistons are driven by a cam on the pump shaft
- C. As the shaft rotates, the cam moves the pistons
- D. On the downward stroke of each piston, a spring-loaded valve opens and fluid is drawn into the piston cylinder from the pump inlet
- E. During the upward stroke the inlet valve is forced closed and another valve directs the oil to the outlet

## INFORMATION SHEET

### XII. Types of axial piston pumps

- A. In-line
- B. Bent-axis

### XIII. Construction and operation of axial piston pumps

#### A. In-line (Transparency 3)

1. The pistons are installed in a circular cylinder block (Transparency 4)
2. The cylinder block is attached to the pump shaft and rotates with the shaft
3. The pistons extend out the cylinder block to contact a fixed plate, called the swash plate, which is installed at an angle and does not rotate
4. As the pump shaft rotates, the cylinder block and pistons also turn
5. Since the swash plate is fixed (does not rotate) the pistons are forced in and out of the cylinder (Transparency 4)
6. The pump inlet and outlets are positioned so that fluid is drawn into the cylinder bore from the inlet when the piston is retracted and forced out the outlet when the piston is extended
7. The port plate (also called valve plate) is a stationary plate which directs the flow in the correct direction

#### B. Bent-axis (Transparency 5)

1. The bent-axis pump consists of a drive member connected to the pump shaft
2. The pistons are installed in a cylinder block
3. The cylinder block is mounted at an angle to the pump shaft and drive member
4. As the pump shaft turns, the drive member and cylinder block are also turned
5. Since pistons are attached to the drive member, they are forced to reciprocate (move in and out) in the cylinder bore
6. During the downward stroke (retracting) fluid is pulled into the cylinder bore from the inlet port



## INFORMATION SHEET

7. During the upward stroke fluid is pushed out of the cylinder bore to the outlet port

### **XIV. Operation of a variable displacement axial piston pump (Transparency 6)**

- A. The displacement of an axial piston pump can be changed by changing the angle the swash plate makes with the pump shaft
- B. The displacement is determined by the piston's travel into and out of the cylinder barrel

(NOTE: A small swash plate angle causes a small amount of piston travel and therefore small displacement. Similarly, a large angle causes large displacement.)

- C. Varying the displacement is a common method of changing the flow rate of a pump when the pump speed (RPM) is fixed
- D. Hand screws and hydraulic cylinders are two means of varying the swash plate angle

### **XV. Parts of a servo-controlled variable displacement pump (Transparency 7)**

- A. Tilting swash plate
- B. Upper servo cylinder
- C. Lower servo cylinder

(NOTE: The upper and lower servo cylinders are used to position the swash plate to the correct angle and hold it at that angle. Hydraulic cylinders are used because of the very large forces required to move and hold the swash plate.)

- D. Control lever

(NOTE: The control lever is used to set a desired displacement.)

- E. Displacement control valve

(NOTE: When the control lever is moved, the displacement control valve is opened to direct flow to the correct servo cylinder to move the swash plate. As the swash plate moves to the correct position, the linkage connecting the swash plate, control valve, and control lever tends to close the valve. When the swash plate reaches the correct position the valve closes to trap fluid in the two servo cylinders and hold the swash plate in the correct position. This servo system allows the large forces required for moving and holding the swash plate to be controlled by much smaller forces at the control lever.)

## INFORMATION SHEET

### F. Charge pump

(NOTE: Most piston pumps require a charge pump on the inlet. This insures that the cylinders fill with oil and that the pistons maintain contact with the swash plate at all times. Servo-controlled variable displacement pumps also use this for force (pressure) for the servo system. The charge pump is usually a gear pump which supplies the fluid at the inlet of the piston pump in the range of 25 to 150 PSI. The charge pump may be physically a part of the piston pump or may be externally mounted.)

### XVI. Components and functions of pressure compensated axial piston pumps (Transparency 8)

(NOTE: Many hydraulic systems are designed to operate with a constant pressure at the outlet of the pump. Because the amount of flow required from the pump by the rest of the system may change, the displacement of the pump must be changed. A pump which will automatically change its displacement (in order to keep a constant pressure) is known as a pressure compensated pump.)

#### A. Swash plate — Varies the displacement of the pump

(NOTE: The term yoke is often used instead of swash plate. Although yoke is a more common term when discussing pressure compensated pumps, either is acceptable.)

#### B. Swash plate (yoke) return cylinder — Normally holds the pump at full displacement

#### C. Servo cylinder — Moves and holds the swash plate

#### D. Compensator adjustment spring — Used to set the compensator pressure, that is, the pressure at the pump outlet

#### E. Compensator (servo) valve — Controls the flow of oil to the servo cylinder

(NOTE: When the force on the servo valve created by the outlet pressure is exactly balanced by the compensator spring, fluid flow to the servo cylinder is blocked. When the outlet pressure is too low, the valve shifts to allow the fluid in the cylinder to be released to the pump case thus causing the pump displacement to increase. When the outlet pressure is too high, the valve shifts the other direction to allow the fluid from the outlet to flow into the servo cylinder and decrease the displacement.)

#### F. Drain to case — Drains fluid from the servo cylinder to the pump case

(NOTE: In addition, continuous flow from the pump outlet is maintained through the case. This provides cooling flow for the pump.)

#### G. Load pressure (outlet pressure) — Used to shift the compensator valve

## INFORMATION SHEET

### XVII. Causes of hydraulic pump cavitation

(NOTE: Cavitation occurs when there is not ample fluid to fill the pumps inlet and air bubbles form. When these bubbles collapse, a small implosion (inward explosion) occurs which tends to erode and destroy the pump's internal surfaces.)

A. Restriction in the pump inlet line

(NOTE: A restriction in the inlet line can cause a drop in the pressure at the pump inlet. This low pressure allows the formation of the air bubbles and thus cavitation.)

B. Replacing pump inlet lines with lines which are too small

(NOTE: Lines too small can also cause low pressure at the pump inlet.)

C. Placing reservoir too far from pump

(NOTE: Long lines to the pump can cause low inlet pressure.)

D. Low fluid level in reservoir

(NOTE: Low fluid level can cause the pump to "starve.")

### XVIII. Common causes of hydraulic pump failure

A. Contaminated fluid

(NOTE: This is one of the most common causes of pump failure. Contamination includes not only solid particles, but also other contaminants such as water and air.)

B. Improper fluid

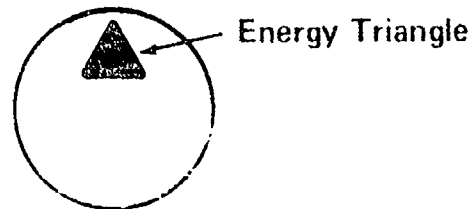
(NOTE: The incorrect fluid may result in pump failure in a very short time. The fluid must have the correct viscosity properties, temperature range, and additives.)

C. Improper operating procedures

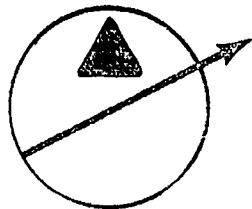
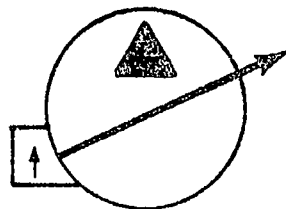
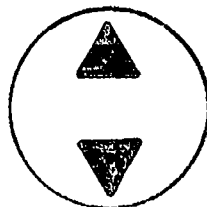
(NOTE: Continuous operation at the pump's maximum limits or exceeding its limits can greatly reduce the pump life. For example, excessive pump pressure or speed can vastly reduce the life of the bearings.)

D. Cavitation

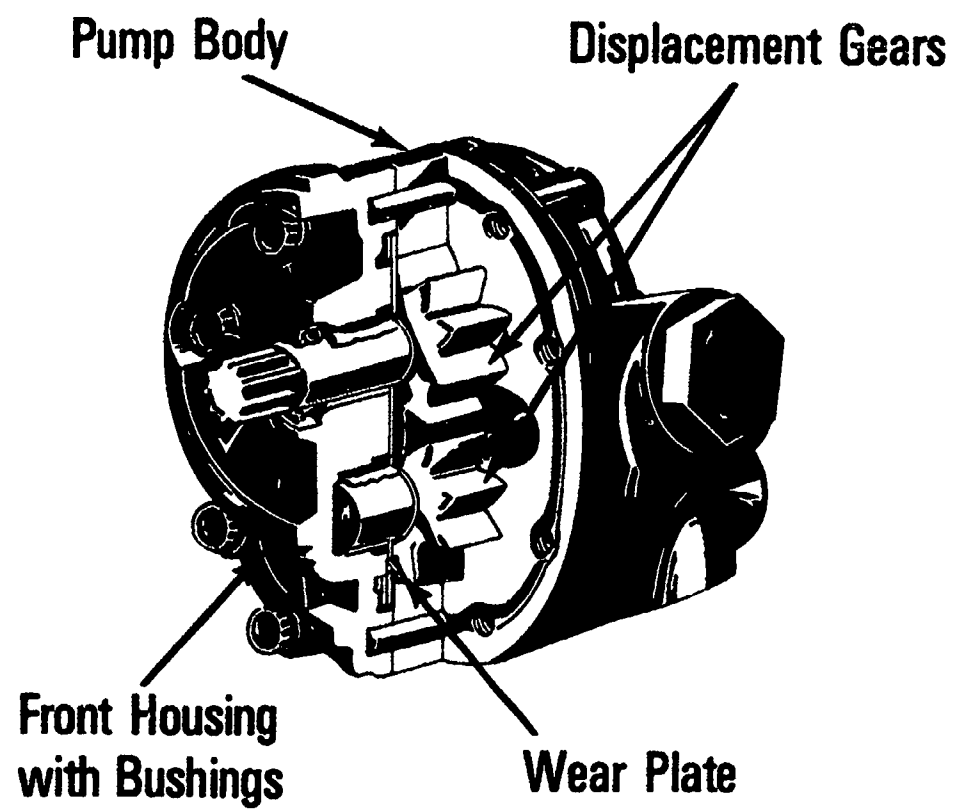
E. Improper pump maintenance

**INFORMATION SHEET****XIX. Symbols for types of pumps****A. Fixed displacement**

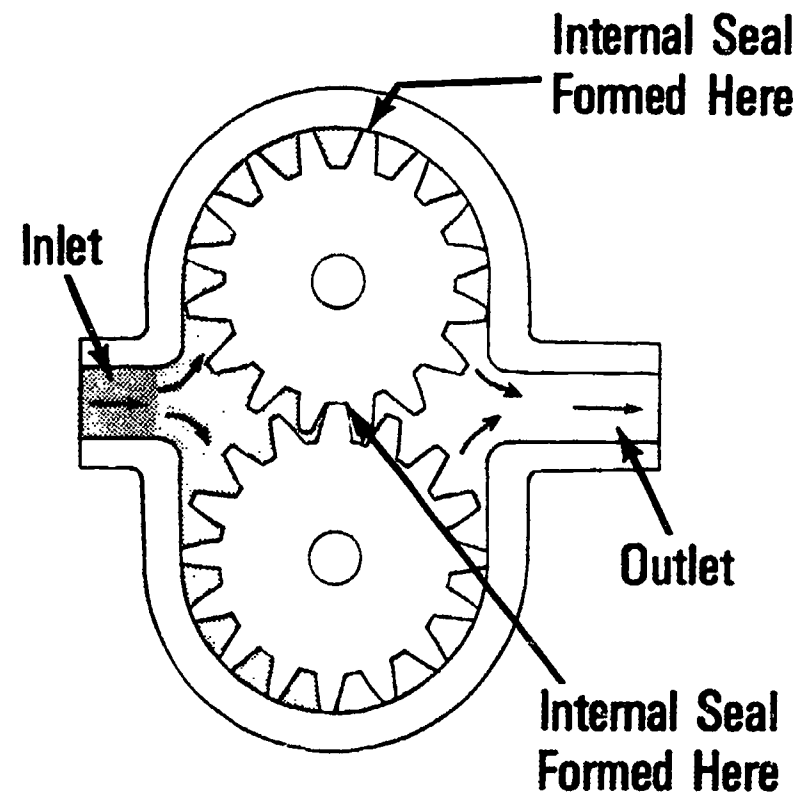
(NOTE: The fluid flow is in the direction of the energy triangle.)

**B. Variable displacement****C. Pressure compensated****D. Bi-directional**

# Gear Pump

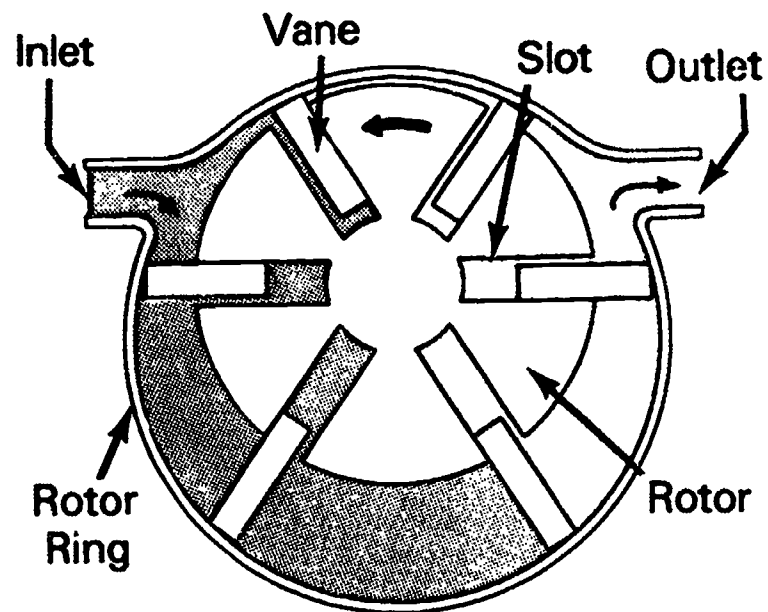


**Gear Pump**

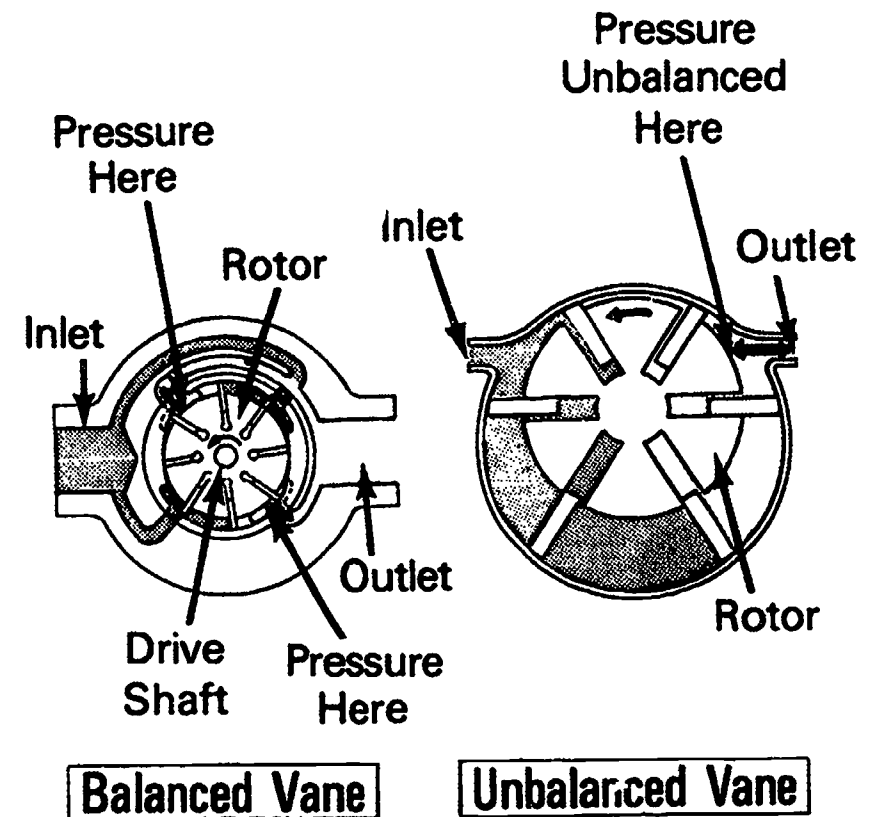


**Operation of Gear Pump**

# Vane Pumps

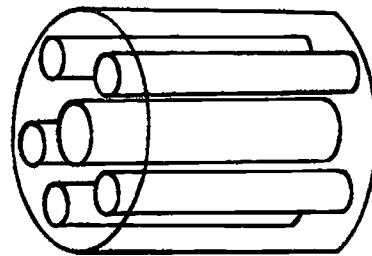


**Unbalanced Vane Pump  
in Operation**

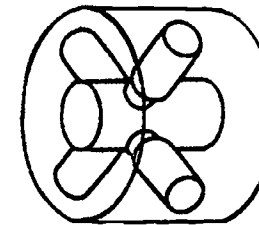


**Balanced vs. Unbalanced Vane Pumps --  
Pressure on Rotor and Shaft**

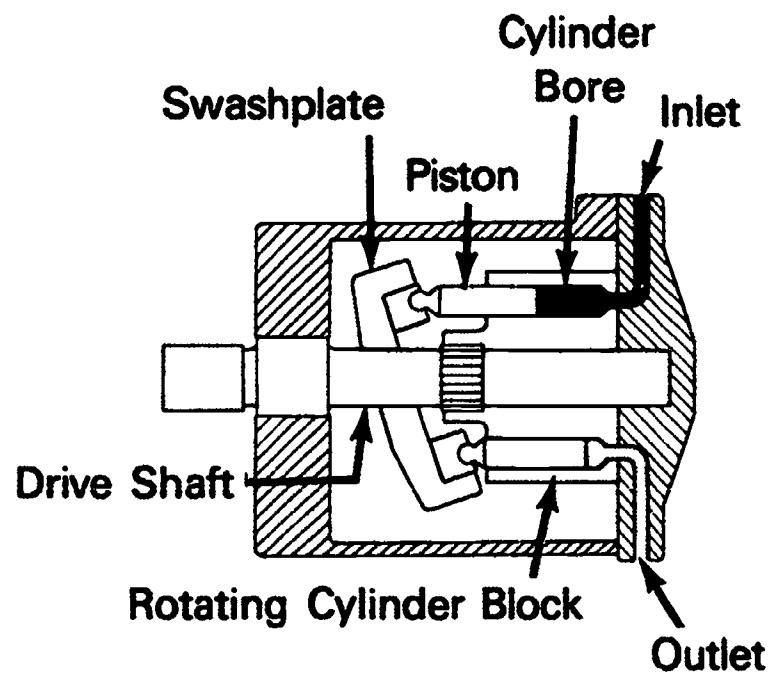
# Types of Piston Pumps



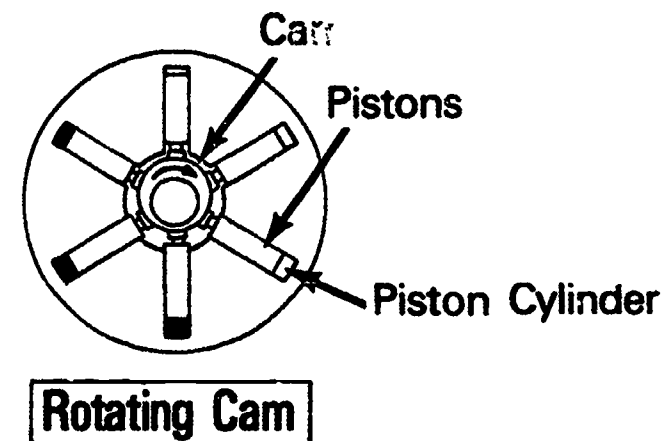
**Axial Piston Pump**



**Radial Piston Pump**

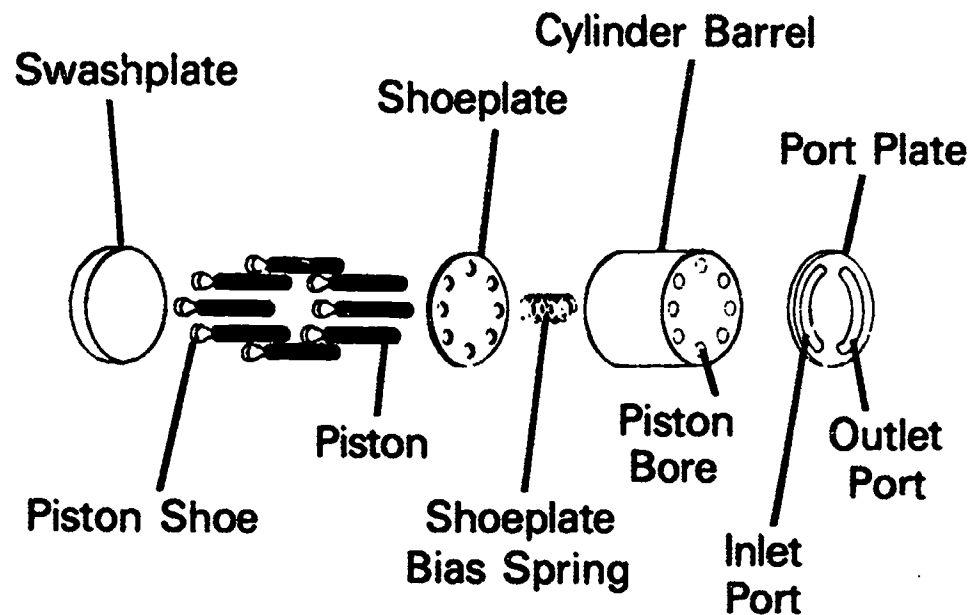


**Operation of an In-line Axial Piston Pump**

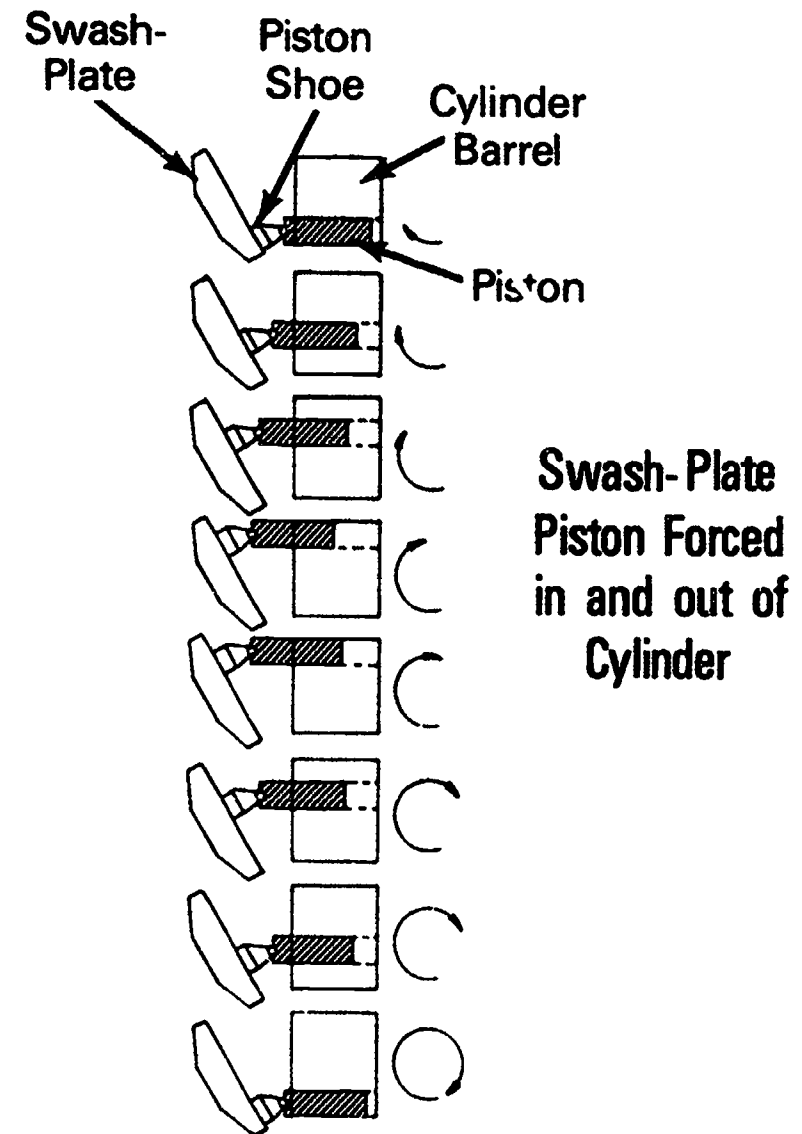


**Operation of Radial Piston Pump**

# Construction and Operation of Axial Piston Pumps

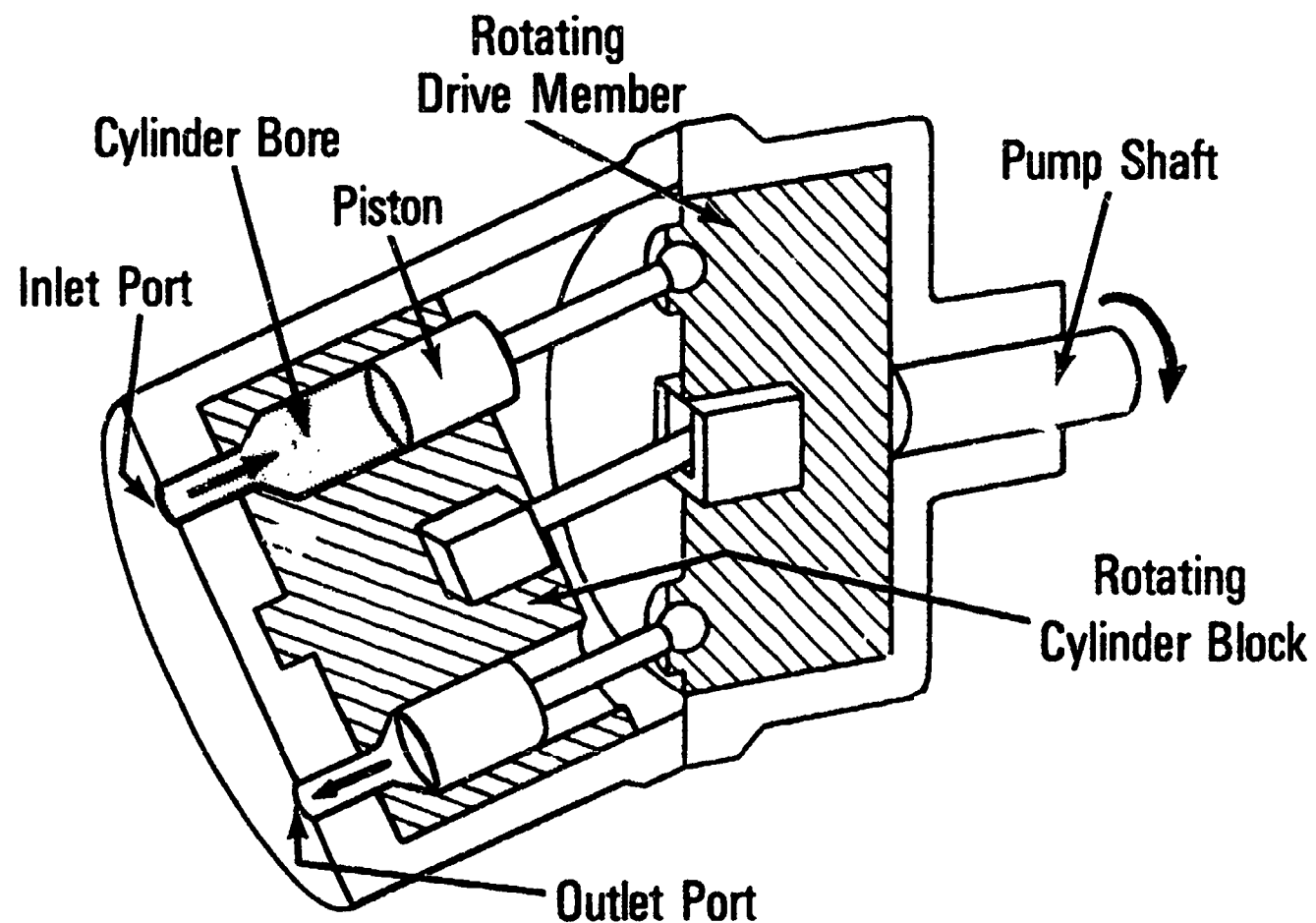


**Piston Installation in Circular Cylinder Block**

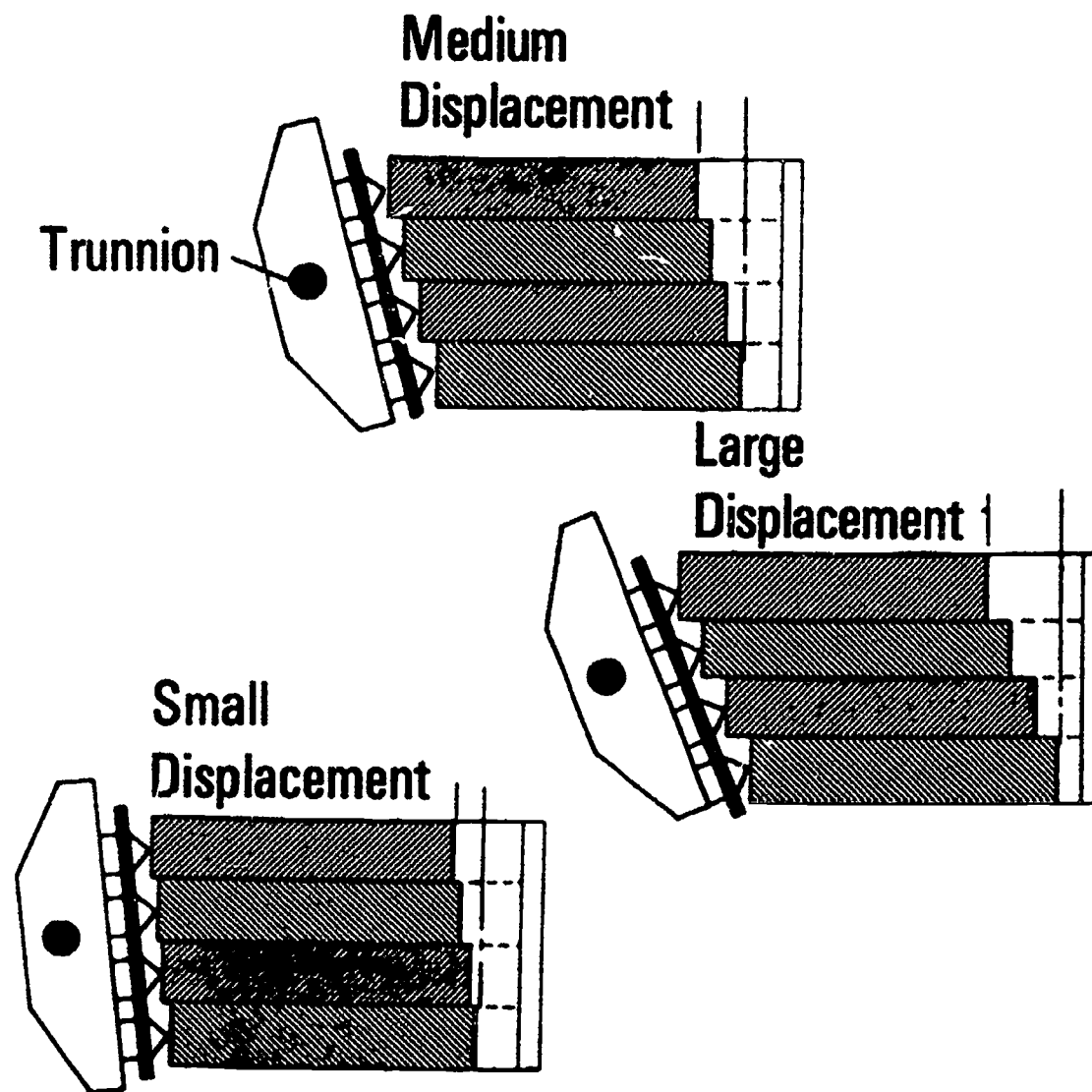




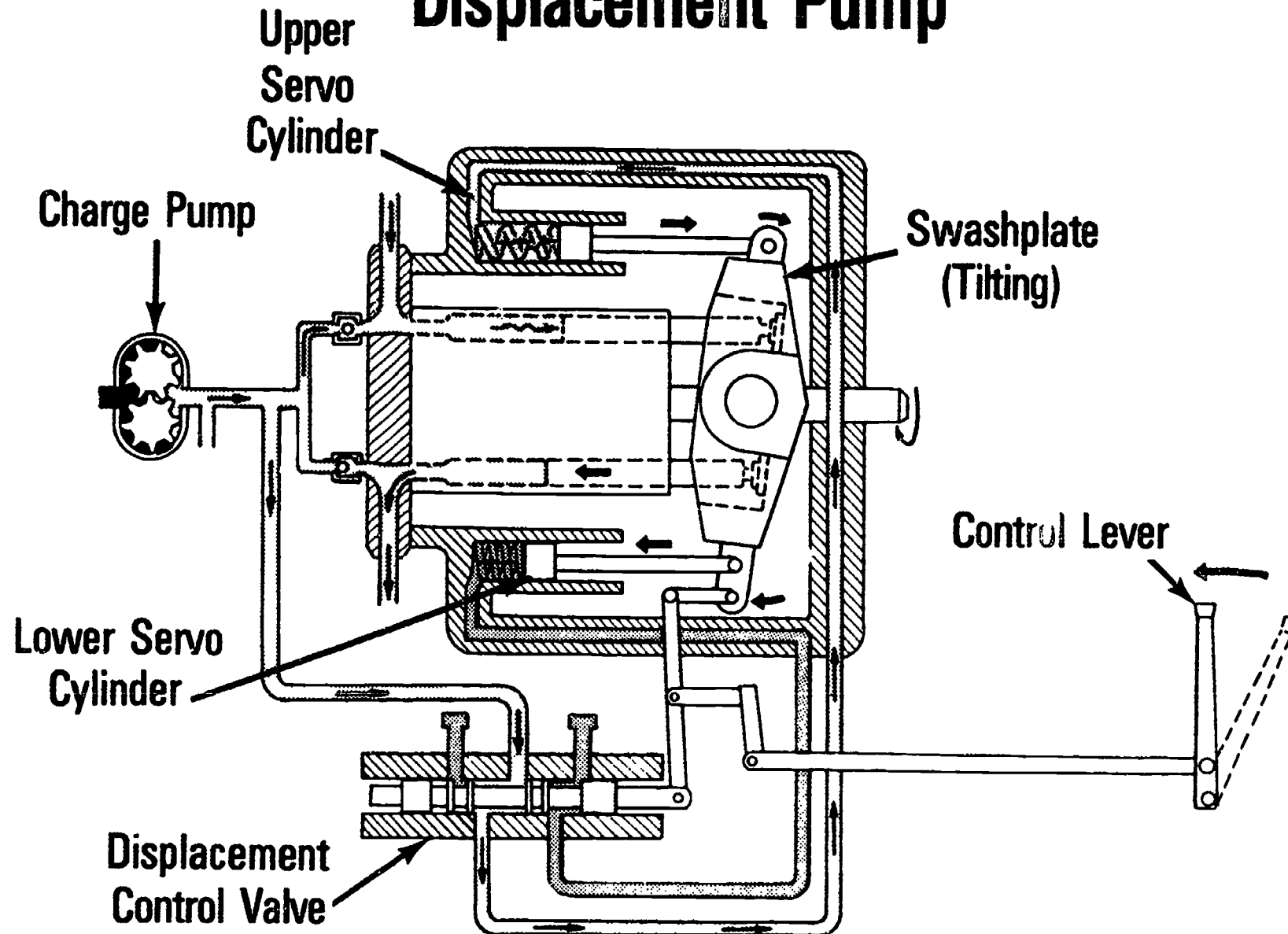
# Bent-Axis Axial Piston Pump — Fixed Displacement



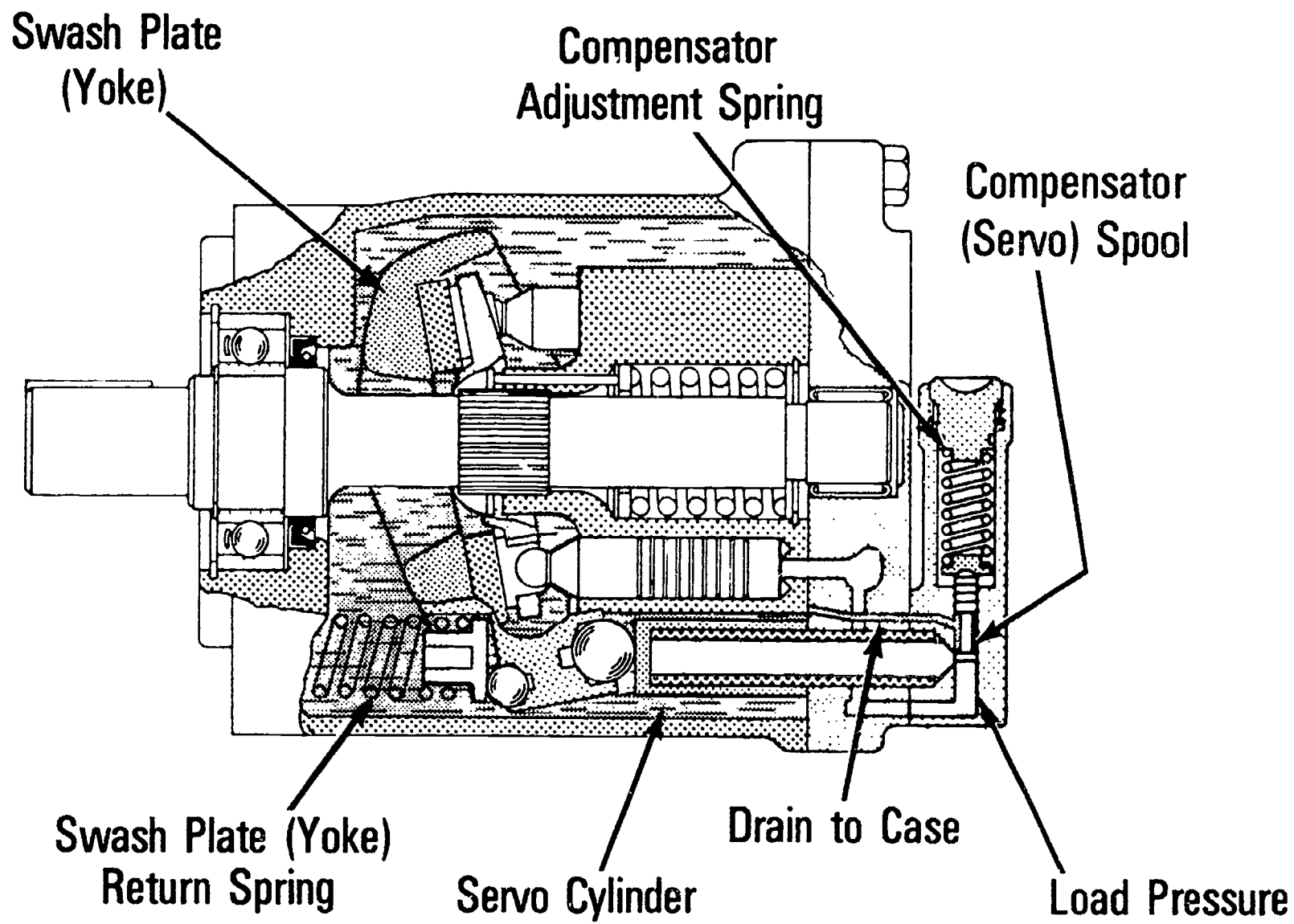
# Operation of Variable Displacement Axial Piston Pump



# Parts of a Servo-Controlled Variable Displacement Pump



# Operation of Pressure Compensated Axial Piston Pumps



## PUMPS UNIT VII

### ASSIGNMENT SHEET #1 — CALCULATE PUMP DISPLACEMENT, FLOW RATE, INPUT AND OUTPUT POWER, AND OVERALL EFFICIENCY

Directions: Solve the following problems using the formula which applies to that problem.

$$\text{Pump displacement} = d = \frac{231 Q}{n}$$

$$\text{Pump flow rate} = Q = \frac{n \times d}{231}$$

$$\text{Pump output power} = \text{HP} = \frac{P \times Q}{1714}$$

$$\text{Pump input power} = \text{HP} = \frac{n \times \text{Torque}}{5252}$$

$$\text{Pump overall efficiency} = \frac{\text{Output power}}{\text{Input power}}$$

- A. What is the pump displacement when the flow rate is 23 GPM at 1900 RPM?  
\_\_\_\_\_
- B. What is the flow rate of a 3.0 in<sup>3</sup>/rev. pump operating at 2600 RPM?  
\_\_\_\_\_
- C. What is the output power of a pump with 21 GPM flow and 3200 PSI outlet pressure?  
\_\_\_\_\_
- D. What is the input power of a pump operating at 2500 RPM with a shaft torque of 70 ft. lbs.?  
\_\_\_\_\_
- E. What is the overall efficiency of a pump if the output power is 40 HP and the input power is 46 HP?  
\_\_\_\_\_
- F. What is the flow rate of a 3.12 in<sup>3</sup>/rev. pump operating at 2200 RPM?  
\_\_\_\_\_

**ASSIGNMENT SHEET #1**

- G. What is the input power of a pump operating at 3000 RPM with a shaft torque of 75 ft. lbs.?

---

- H. What is the pump displacement if the outlet flow is 26 GPM at 2000 RPM?

---

- I. What is the output power of a pump with a 25 GPM flow and 3000 PSI pressure?

---

## PUMPS UNIT VII

### ANSWERS TO ASSIGNMENT SHEET

- A. 2.80 in/rev.
- B. 34 GPM
- C. 39 HP
- D. 33 HP
- E. 87%
- F. 29.7 GPM
- G. 43 HP
- H. 3 in/rev.
- I. 44 HP

## PUMPS UNIT VII

### JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A GEAR PUMP

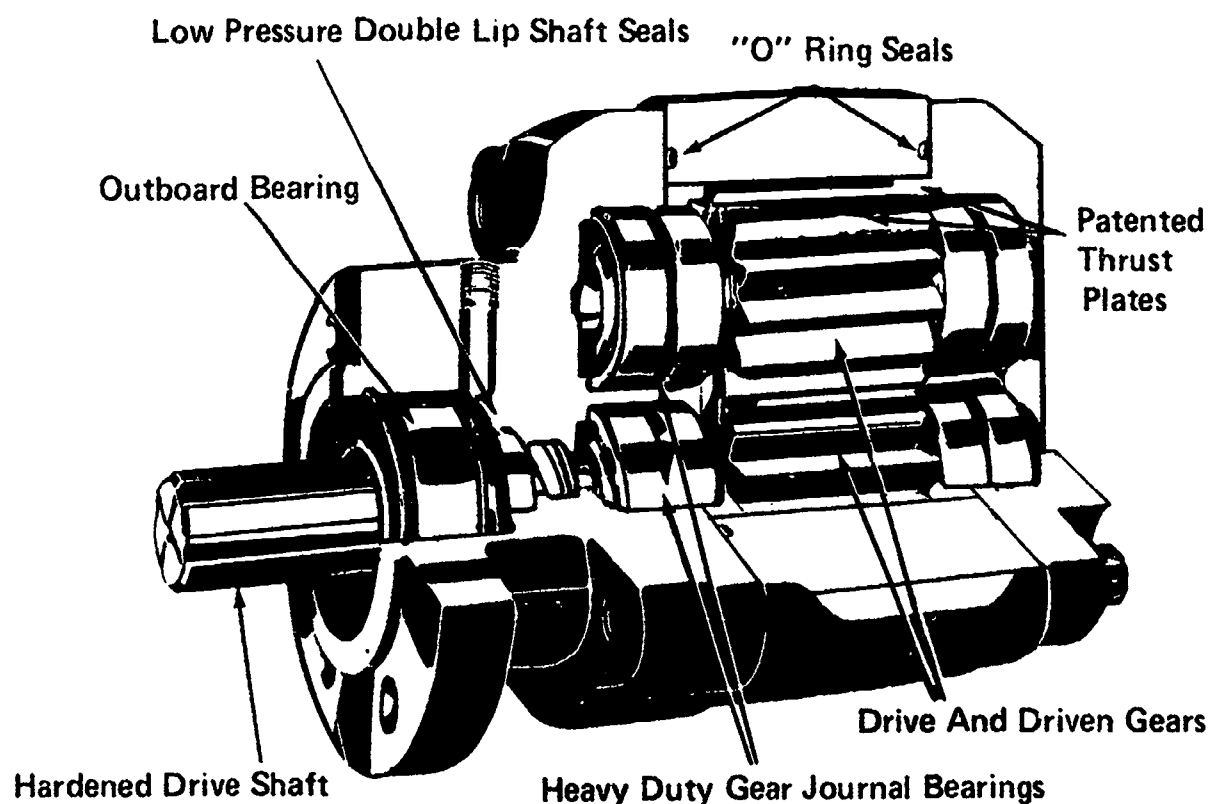
A. Tools and materials

1. Gear pump
2. Service manual for pump (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

B. Routine #1 — Disassemble the pump

(NOTE: Figure 1 shows a cut-away drawing of a typical gear pump with an outboard bearing on the pump shaft. Figure 2 is an exploded view of this pump.)

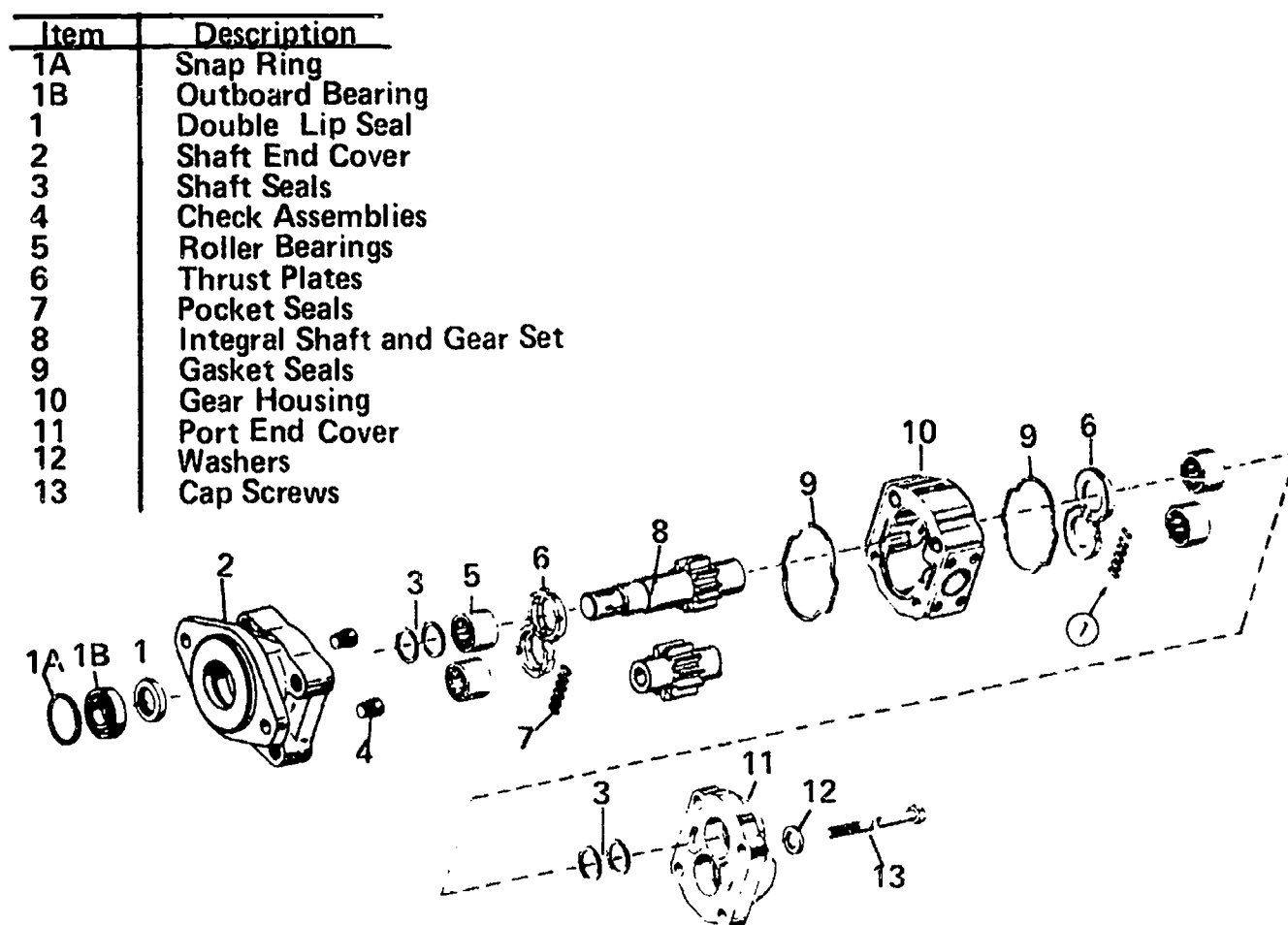
FIGURE 1





## JOB SHEET #1

FIGURE 2



1. Thoroughly clean the external surfaces of the pump with solvent
2. Dry the pump with shop towels
3. Place the pump on a clean surface for disassembly
4. Remove the clip ring retainer on the outboard shaft bearing (if used)
5. Remove the bearing
6. Remove the four cap screws which hold the pump housing together
7. Slowly remove the port (rear) end cover from the pump
8. Remove the two port side roller bearings from the assembly
9. Remove the rear thrust plate  
(NOTE: Note the orientation of the plate.)
10. Remove the gear housing from the pump

**JOB SHEET #1**

11. Carefully remove the two gears from the pump
12. Remove the shaft side thrust plate noting orientation
13. Remove the two shaft side roller bearings
14. Remove shaft seal

☐ Have your instructor check your work

**C. Routine #2 — Inspect the pump**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine the two thrust plates for excessive wear or scoring		
2. Examine the gears for excessive wear and broken teeth		
3. Examine the roller bearings for excessive wear and fractured bearings		
4. Examine the shaft seal for scoring		
5. Examine the gear housing seals (usually O-rings) for nicks or breaks		
6. Replace any part found to be defective		

☐ Have your instructor check your work

**D. Routine #3 — Reassemble the pump**

(NOTE: Pre-lube parts during assembly.)

1. Carefully install the shaft seal
2. Install the two shaft side roller bearings
3. Install the shaft side thrust plate
4. Install the two gears into the shaft end cover

**JOB SHEET #1**

5. Insure that the two seals on the gear housing are properly installed and then lower the gear housing around the two gears and align with the shaft end cover
6. Install the port side thrust plate
7. Install the port side roller bearings
8. Install the port side end cover onto the assembly and carefully align
9. Install the four cap screws
10. Uniformly torque the screws by alternately applying torque to screws on opposite sides of the pump
11. Reinstall the shaft outboard bearing and clip ring
12. Fill pump with fluid as necessary before operation
- ☐ Have your instructor check your work
13. Clean up area and return tools and materials to proper storage

## PUMPS UNIT VII

### JOB SHEET #2 — DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE COMPENSATED VARIABLE DISPLACEMENT PUMP

#### A. Tools and materials

1. Pressure compensated pump

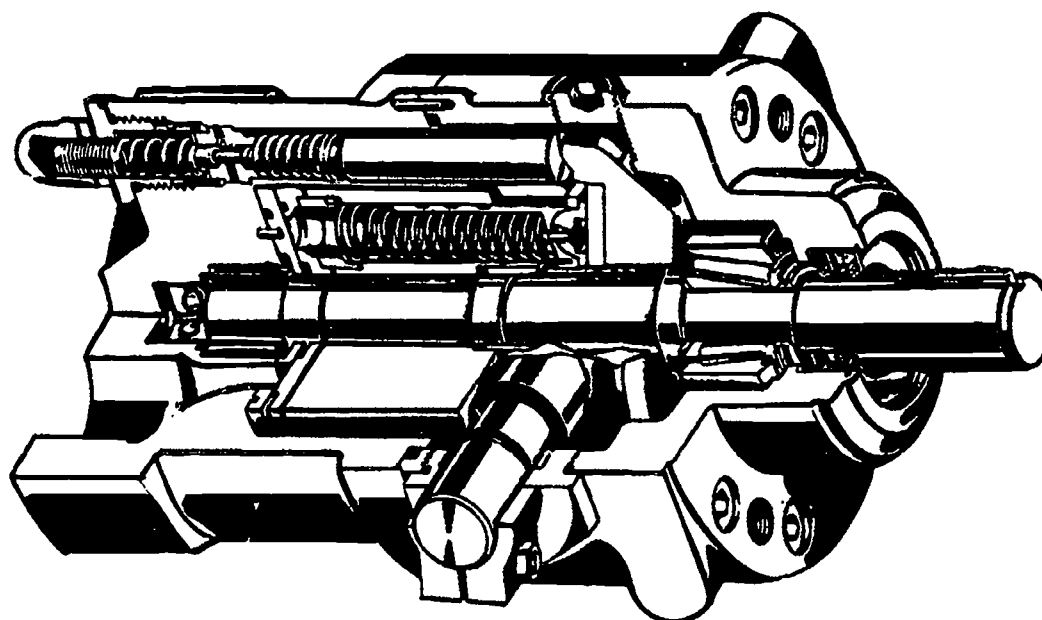
(NOTE: This job sheet assumes that an in-line axial piston pump will be used. The procedures are similar for other types of pressure compensated pumps.)

2. Service manual for pump
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

#### B. Routine #1 — Disassemble the pump

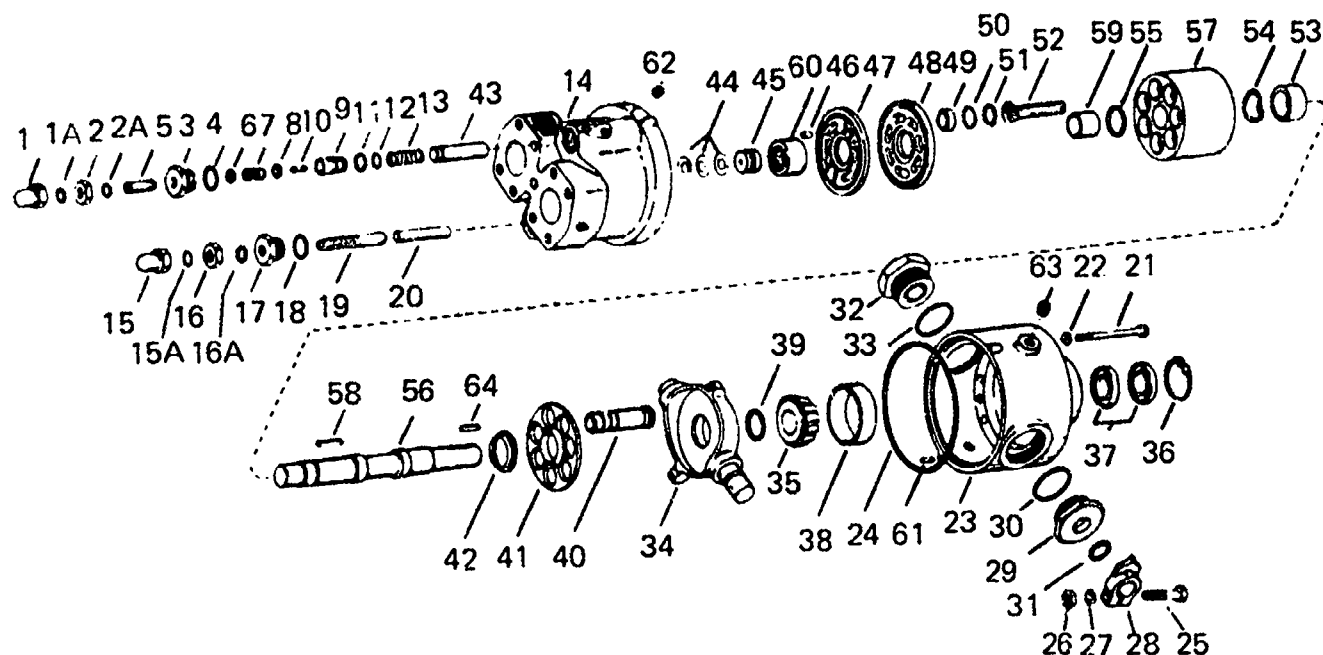
(NOTE: The procedures here assume a pressure compensated in-line axial piston pump. A cut-away view of such a pump is shown in Figure 1. An exploded view of this pump is shown in Figure 2.)

FIGURE 1



## JOB SHEET #2

FIGURE 2

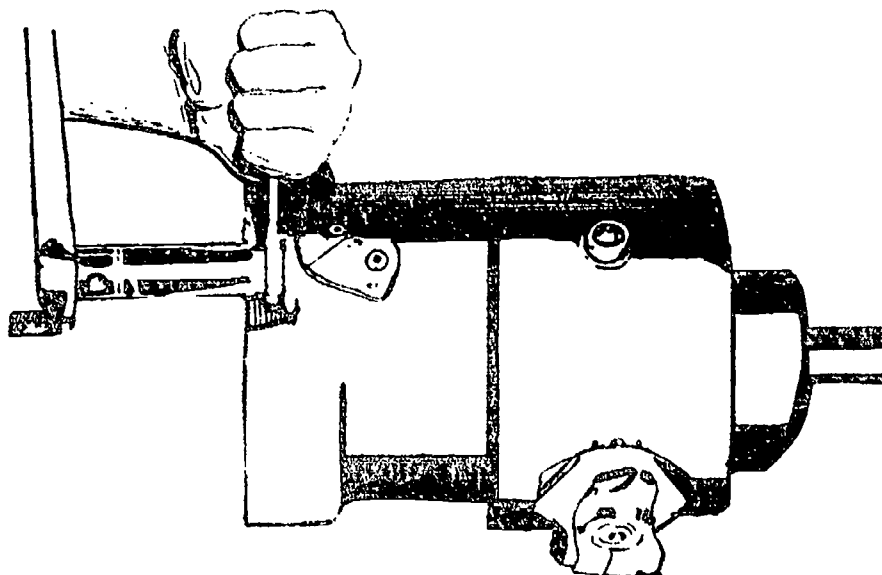


No.	Description	Qty.	No.	Description	Qty.	No.	Description	Qty.
1	Acorn nut	1	20	Control piston	1	42	Ball bushing	1
1A	Packing, preformed	1	21	Cap screw	8	43	Port end cover	1
2	Jam nut	1	22	Washer	8	44	Spring	3
2A	Packing, preformed	1	23	Drive cover	1	45	Bearing	1
3	Adjustment plug	1	24	Preformed packing	1	46	Dowel	1
4	Preformed packing	1	25	Cap screw	1	47	Fixed port plate	1
5	Adjustment screw	1	26	Nut	1	48	Rotating port plate	1
6	Spring seat	1	27	Lockwasher	1	49	Cylinder seal	7
7	Compensator spring	1	28	Indicator	1	50	Preformed packing	7
8	Spring seat	1	29	Thru trunnion nut	1	51	Washer	7
9	Compensator shell	1	30	Preformed packing	1	52	Spring	7
10	Compensator piston	1	31	Preformed packing	1	53	Spring sleeve	1
11	Quad ring	1	32	Blind trunnion nut	1	54	Wave washer	3
12	Quad ring	1	33	Preformed packing	1	55	Snapring	1
13	Starting spring	1	34	Reaction swivel assy	1	56	Drive shaft	1
14	Control piston	1	35	Bearing	1	57	Rotor	1
15	Acorn nut	1	36	Snapring	1	58	Key	1
15A	Packing, preformed	1	37	Seal	2	59	Bearing race	1
16	Jam nut	1	38	Bearing cup	1	60	Bearing	1
16A	Packing, preformed	1	39	Thrust washer	1	61	Case dowel	1
17	Adjustment plug	1	40	Piston assembly	7	62	Pipe plug	1
18	Preformed packing	1	41	Holddown plate	1	63	Pipe plug	1
19	Adjustment screw	1				64	Key	1

**JOB SHEET #2**

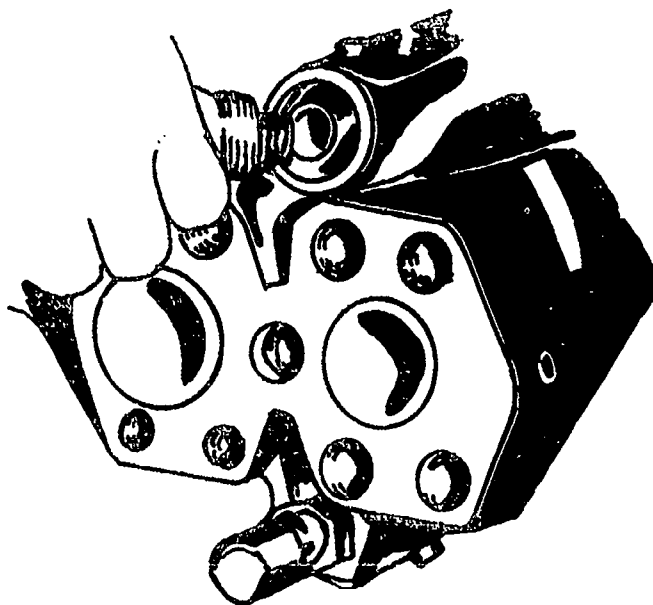
1. Clean the external surfaces of the pump using solvent to remove all dirt and grime
2. Dry pump with shop towels
3. Loosen the jam nut and unscrew the compensator adjustment screw (Figure 3)

FIGURE 3



4. Remove the compensator spring seat and compensator spring (Figure 4)

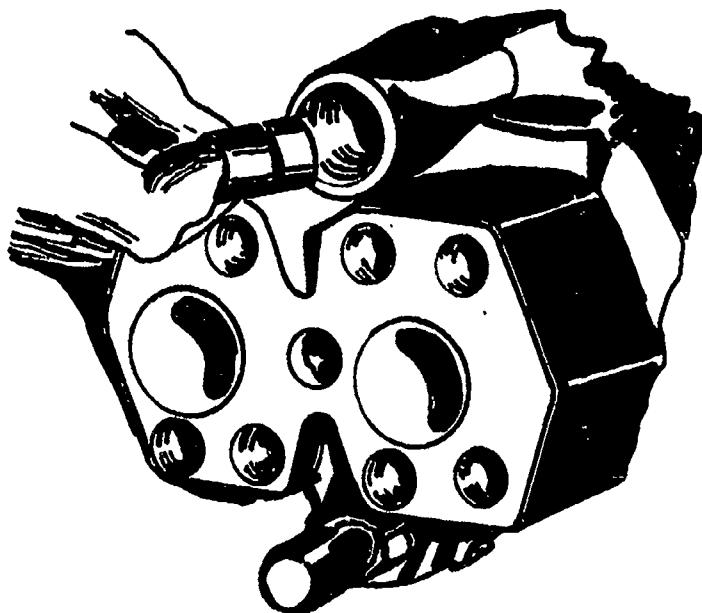
FIGURE 4



**JOB SHEET #2**

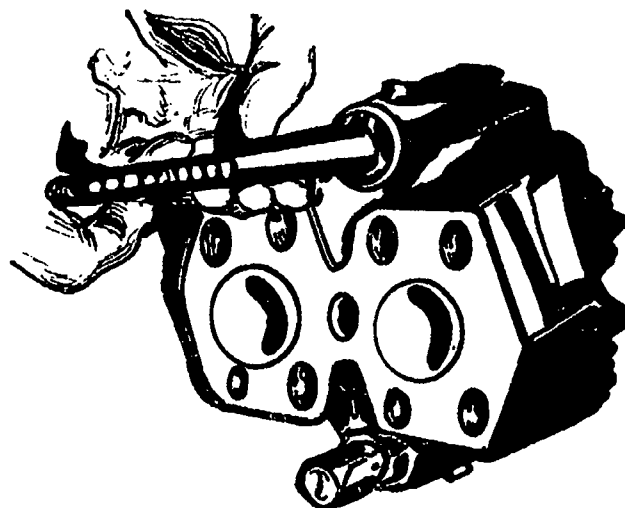
5. Remove the compensator spool (Figure 5)

FIGURE 5



6. Remove the compensator piston and spring (Figure 6)

FIGURE 6

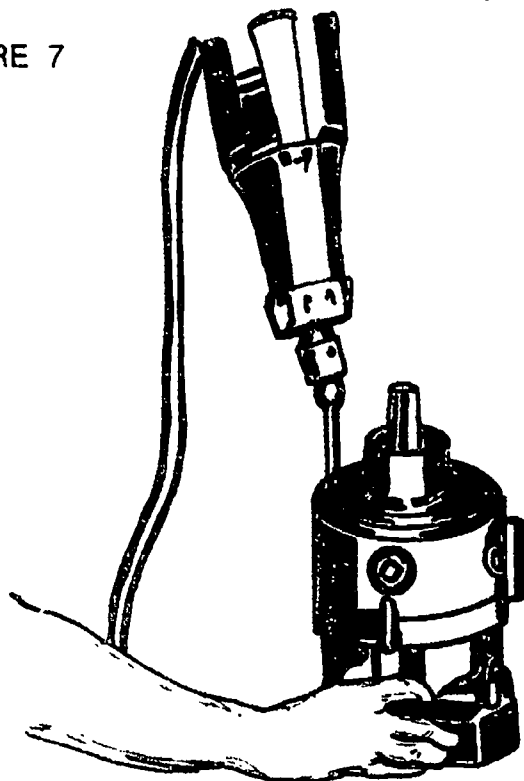


7. Remove the retaining nut for the compensator piston on the other side of the pump
8. Remove the spring and piston

## JOB SHEET #2

9. Unscrew the cap screws that hold the pump housing together (Figure 7)

FIGURE 7



(NOTE: Be careful to lift the cover straight up. Be especially careful to insure that the pistons are free of the swash plate as shown in Figure 8.)

10. Carefully remove the drive end cover from the port end cover (Figure 9)

FIGURE 8

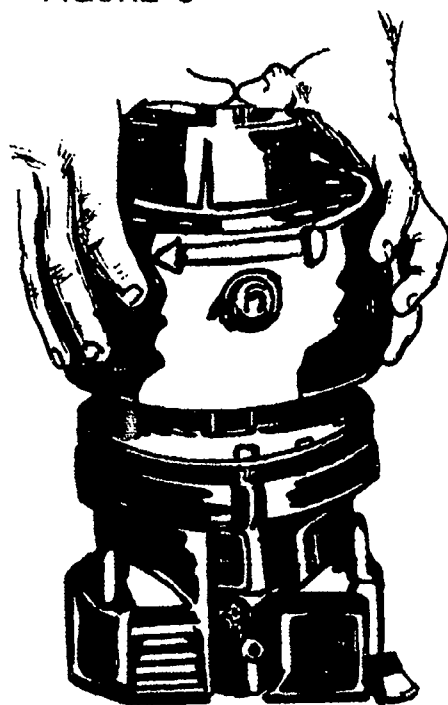


FIGURE 9

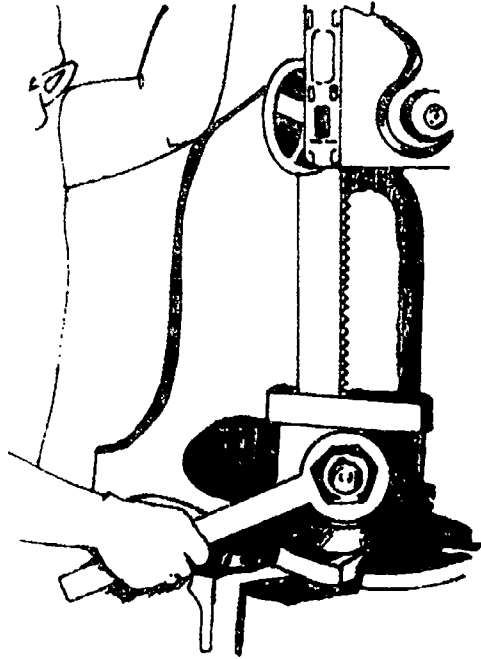




**JOB SHEET #2**

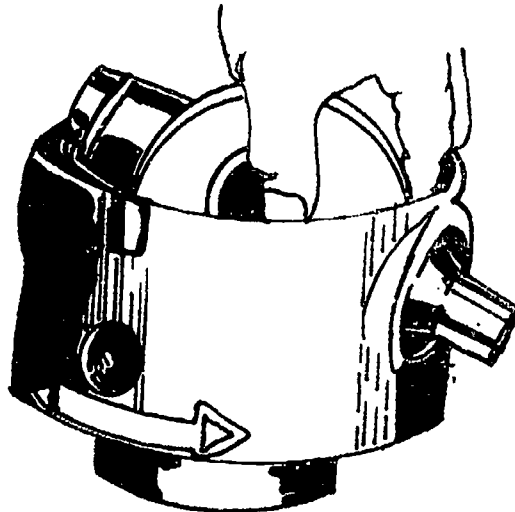
11. Remove the trunnion nut from the assembly (Figure 10)

FIGURE 10



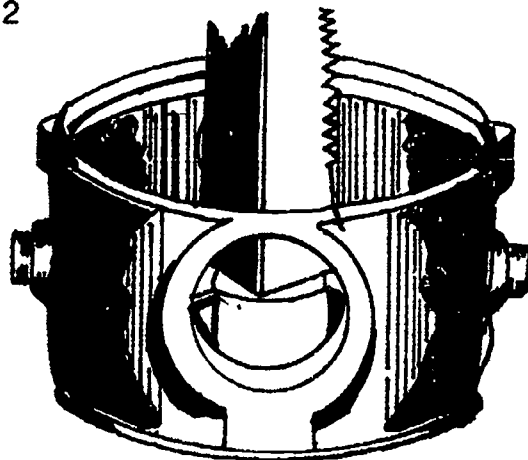
12. Remove the swash plate from the drive cover (Figure 11)

FIGURE 11



13. Remove the snap ring, seals and bearings from the shaft cover (Figure 12)

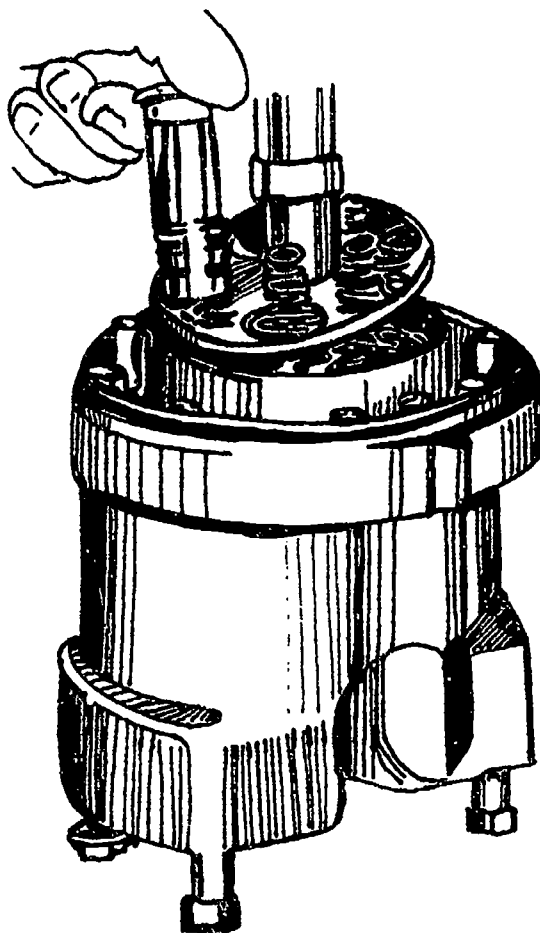
FIGURE 12



**JOB SHEET #2**

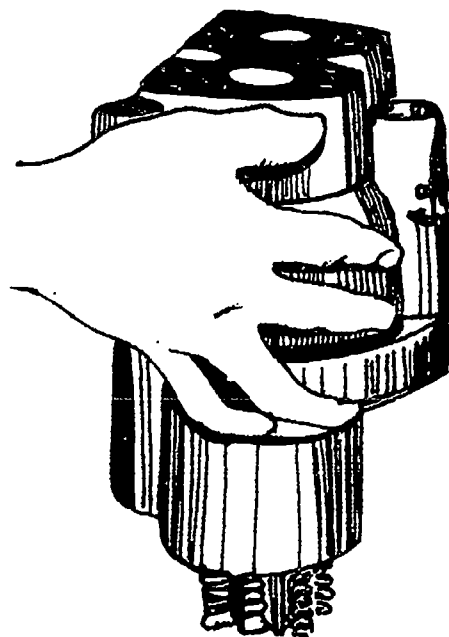
14. Remove the pistons from the assembly (Figure 13)

FIGURE 13



15. Remove the port end cover from the barrel and shaft assembly (Figure 14)

FIGURE 14



## JOB SHEET #2

16. Remove the port plate from the port end cover (Figure 15)

FIGURE 15



- ☐ Have your instructor check your work

C. Routine #2 — Inspect the pump

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Inspect the pistons and piston bore for scoring or excessive wear		
2. Inspect the piston shoe for excessive wear		
3. Examine the swash plate for excessive wear		
4. Inspect the shaft seat for scoring and excessive wear		
5. Examine the compensator piston		
6. Examine the compensator piston		
7. Inspect the compensator fluid passages for blockage and clean if necessary		
8. Examine the port plate for wear or cracking		

- ☐ Have your instructor check your work

**JOB SHEET #2****D. Routine #3 — Reassemble the pump**

1. Install the port plate into the port end housing
2. Place the cylinder barrel and shaft assembly into the port end housing
3. Install the pistons into the assembly
4. Install the bearing, seal and seal-retainer ring into the shaft end cover
5. Install the swash plate into the shaft end cover
6. Install the trunnion nut to secure the swash plate
7. Make sure the port end cover is lying on a flat surface with the ports down, and carefully lower the shaft end cover onto the assembly
8. Make sure that the piston shoes properly contact the swash plate
9. Install the cap screws to secure the two halves of the pump assembly
10. Torque the screws to manufacturer's recommended specifications by tightening screws on opposite sides of the pump in sequence
11. Install the lower piston with spring and tighten screw cap
12. Install the upper piston with spring, compensator spool, spool spring, and adjustment screw
13. Tighten adjustment screw only partially into the pump
- ☐ Have your instructor check your work
14. Clean up area and return tools and materials to proper storage

# PUMPS UNIT VII

NAME \_\_\_\_\_

## TEST

1. Match the terms on the right with the correct definitions.

- |         |  |                          |
|---------|--|--------------------------|
| _____a. | A device which creates the flow of fluid   | 1. Displacement          |
| _____b. | The volume of fluid which is transferred from the pump inlet to the outlet during one revolution of the pump | 2. Back pressure         |
| _____c. | The actual flow rate from a pump divided by the theoretical flow rate  | 3. Pump                  |
| _____d. | The formation of air bubbles in the inlet of a pump because the inlet does not completely fill with fluid    | 4. Volumetric efficiency |
| _____e. | Air in the fluid   | 5. Cavitation            |
| _____f. | Pressure in the return line caused by flow through the line from the pump to the reservoir                   | 6. Aeration              |

2. Distinguish between positive and nonpositive displacement pumps by placing an "X" next to the description of positive displacement pumps.

- |         |   |  |
|---------|---|--|
| _____a. | A pump whose inlet and outlet are hydraulically connected so that fluid can recirculate in the pump when pressure builds up |  |
| _____b. | A pump whose inlet is sealed from the outlet; will deliver fluid any time the inlet is kept supplied and the pump is driven |  |

3. Name three kinds of positive displacement pumps.

- |    |  |
|----|--|
| a. |  |
| b. |  |
| c. |  |

4. Calculate the pump displacement for a pump which has an outlet of 30 GPM at 200 RPM, using the formula for displacement,  $d = \frac{231 Q}{n}$

## TEST

5. Calculate the flow rate for a 2.88 in<sup>3</sup>/rev. pump operating at 2000 RPM using the formula for flow rate,  $Q = \frac{n \times d}{231}$
6. a. Calculate the output power for a pump operating with 18 GPM flow and 2700 PSI outlet pressure using the formula,  $\text{Power} = \frac{P \times Q}{1714}$
- b. Calculate the input power for a pump operating at 2000 RPM with a shaft torque of 50 ft. lbs. using the formula,  $\text{Power} = \frac{n \times \text{Torque}}{5252}$
7. Calculate the volumetric efficiency of a 2.56 in<sup>3</sup>/rev. pump operating at 2300 RPM with an outlet flow rate of 22 gallons per minute (GPM).

**TEST**

8. Discuss the operation of a gear pump.

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9. Select true statements concerning the operation of vane pumps by placing an "X" next to the statements which are true.

- \_\_\_\_\_a. A fixed displacement vane pump consists of a slotted rotor inside a circular chamber
- \_\_\_\_\_b. In a fixed displacement pump, vanes are installed into the slots in the rotor and are free to move in an axial direction
- \_\_\_\_\_c. As the rotor rotates in a fixed displacement pump, the vanes are forced outward to contact the surface of the circular chamber
- \_\_\_\_\_d. In a fixed displacement pump, as the rotor rotates a vane past the inlet port, a volume of fluid is trapped between two vanes
- \_\_\_\_\_e. Because the rotor is installed offset in the circular chamber in the fixed displacement pump, the volume contained between two rotors becomes smaller and the trapped fluid is expelled from the outlet
- \_\_\_\_\_f. The trapped fluid is expelled from the outlet of the pump and is at a lesser pressure than the inlet
- \_\_\_\_\_g. In a variable displacement pump, the displacement vane can be changed by changing the position of the rotor in the circular chamber

10. Distinguish between axial and radial piston pumps by placing an "X" next to the description of an axial piston pump.

- \_\_\_\_\_a. Pistons are parallel to the axis of the pump
- \_\_\_\_\_b. Pistons are perpendicular to the axis of the pump

## TEST

11. Select true statements concerning the operation of a radial piston pump by placing an "X" next to the statements which are true.

\_\_\_\_\_a.    **Pistons are installed radially to the pump**

       b. The pistons are driven by a cam on the pump shaft

       c. As the shaft rotates, the pistons move the cam

\_\_\_\_\_d. On the downward stroke of each piston, a spring-loaded valve opens and fluid is drawn into the piston cylinder from the pump inlet

\_\_\_\_\_e. During the upward stroke the inlet valve is forced closed and another valve directs the oil to the outlet

- 12. Name two types of axial piston pumps.**

a. \_\_\_\_\_

b. \_\_\_\_\_

- 13. Discuss the construction and operation of axial piston pumps.**

**a. In-line**

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.



## TEST

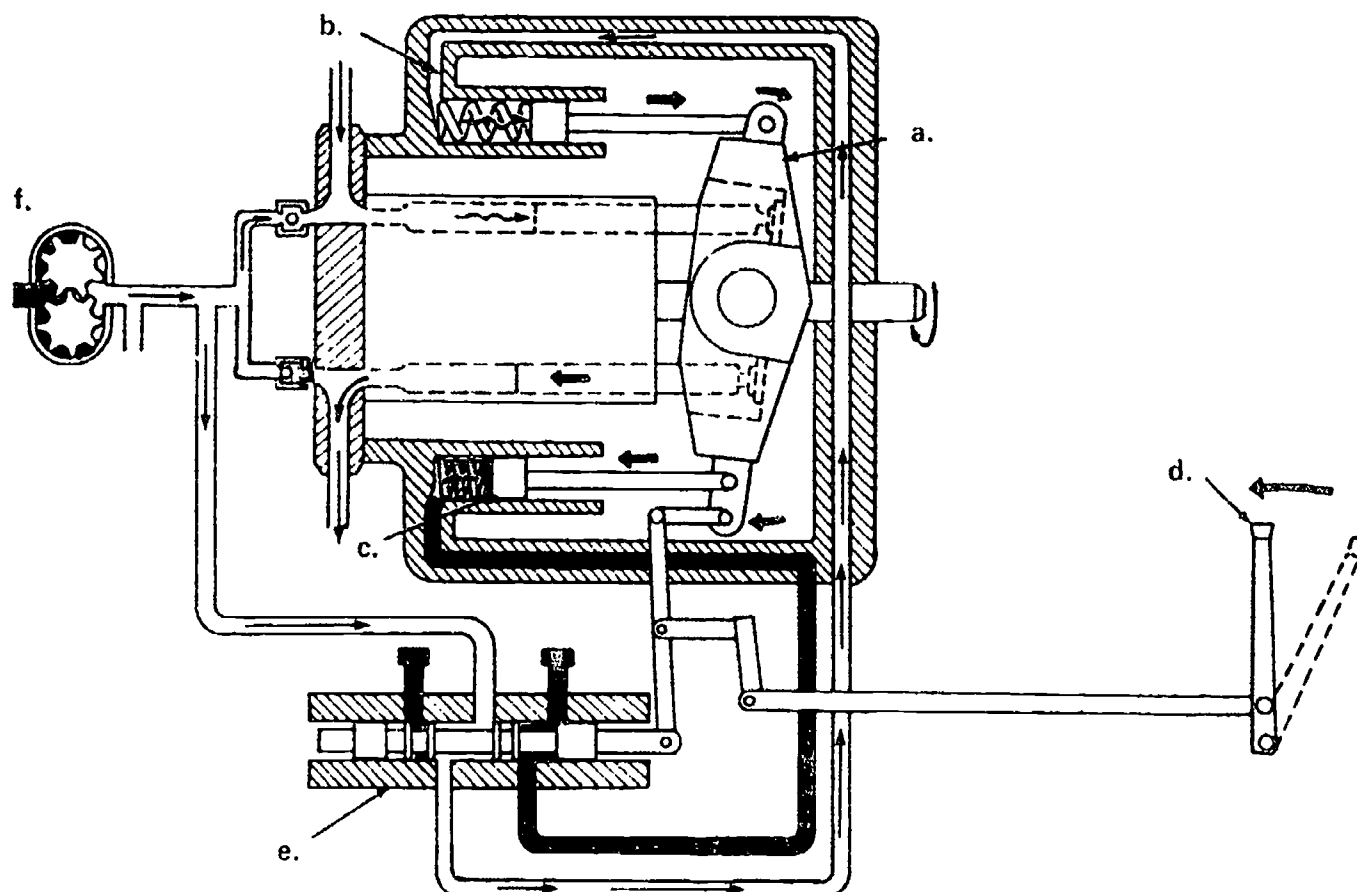
**b. Bent-axis**

[illegible]

14. Select true statements concerning the operation of a variable displacement axial piston pump by placing an "X" next to the statements which are true.
- ☐ a. The displacement of an axial piston pump can be changed by changing the angle the rotor makes with the pump shaft
  - ☐ b. The displacement is determined by the piston's travel into and out of the cylinder barrel
  - ☐ c. Varying the displacement is a common method of changing the flow rate of a pump when the pump speed is fixed
  - ☐ d. Hand screws and hydraulic cylinders are two means of varying the swash plate angle

## TEST

15. Identify the parts of a servo-controlled variable displacement pump.



- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_
- f. \_\_\_\_\_

## TEST

16. Match the components of the pressure compensated axial piston pumps on the right with the correct functions.

_____a.	Varies the displacement of the pump	1. Load pressure
_____b.	Normally holds the pump at full displacement	2. Swash plate return cylinder
_____c.	Moves and holds the swash plate	3. Compensator adjustment spring
_____d.	Used to set the compensator pressure, that is, the pressure at the pump outlet	4. Drain to case
_____e.	Controls the flow of oil to the servo cylinder	5. Swash plate
_____f.	Drains fluid from the servo cylinder to the pump case	6. Servo cylinder
_____g.	Used to shift the compensator valve	7. Compensator valve

17. List four causes of hydraulic pump cavitation.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

18. List four common causes of hydraulic pump failure.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

19. Draw the symbols for the following pumps.

- a. Fixed displacement

**TEST**

b. Variable displacement

c. Pressure compensated

d. Bi-directional

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

20. Demonstrate the ability to:

- a. Disassemble, inspect, and reassemble a gear pump.
- b. Disassemble, inspect, and reassemble a pressure compensated variable displacement pump.

## PUMPS UNIT VII

### ANSWERS TO TEST

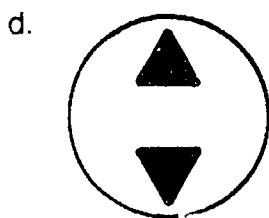
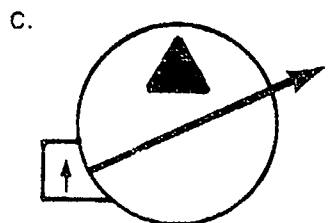
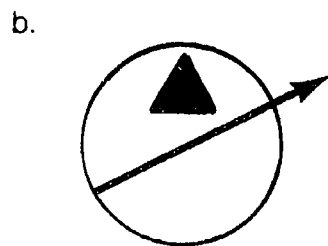
1.   a.     3                   c.     4                   e.     6  
     b.     1                   d.     5                   f.     2
2.   b
3.   Any three of the following:
  - a.     Gear
  - b.     Vane
  - c.     Piston
  - d.     Screw
4.   3.465 in'/rev.
5.   24.9 GPM
6.   a.     28 HP  
     b.     19 HP
7.   86%
8.   Discussion should include:
  - a.     The gear pump consists of two or more gears
    - 1)    Drive gear — Power from engine or motor is applied to this gear
    - 2)    Driven gear — Rotation of driver gear also causes rotation of driven gear
  - b.     As the gears pass the inlet of the pump, the space between the gear teeth fills with fluid
  - c.     The rotation of the gears carries the fluid around the outside perimeter of the gears to the outlet
9.   a, c, d, e, g
10.  a
11.  a, b, d, e
12.  a.     In-line  
     b.     Bent-axis
13.  Discussion should include:
  - a.     In-line
    - 1)    The pistons are installed in a circular cylinder block
    - 2)    The cylinder block is attached to the pump shaft and rotates with the shaft
    - 3)    The pistons extend out the cylinder block to contact a fixed plate, called the swash plate, which is installed at an angle and does not rotate
    - 4)    As the pump shaft rotates, the cylinder block and pistons also turn

## ANSWERS TO TEST

- 5) Since the swash plate is fixed the pistons are forced in and out of the cylinder
  - 6) The pump inlet and outlets are positioned so that fluid is drawn into the cylinder bore from the inlet when the piston is retracted and forced out the outlet when the piston is extended
  - 7) The port plate is a stationary plate which directs the flow in the correct direction
- b. Bent-axis
- 1) The bent axis consists of a drive member connected to the pump shaft
  - 2) The pistons are installed in a cylinder block
  - 3) The cylinder block is mounted at an angle to the pump shaft and drive member
  - 4) As the pump shaft turns, the drive member and cylinder block are also turned
  - 5) Since pistons are attached to the drive member, they are forced to reciprocate in the cylinder bore
  - 6) During the downward stroke fluid is pulled into the cylinder bore from the inlet port
  - 7) During the upward stroke fluid is pushed out of the cylinder bore to the outlet port
14. b, c, d
- 15.
- a. Tilting swash plate
  - b. Upper servo cylinder
  - c. Lower servo cylinder
  - d. Control lever
  - e. Displacement control valve
  - f. Charge pump
- 16.
- |    |   |    |   |    |   |
|----|---|----|---|----|---|
| a. | 5 | d. | 3 | g. | 1 |
| b. | 2 | e. | 7 |    |   |
| c. | 6 | f. | 4 |    |   |
- 17.
- a. Restriction in the pump inlet line
  - b. Replacing pump inlet lines with lines which are too small
  - c. Placing reservoir too far from pump
  - d. Low fluid level in the reservoir
18. Any four of the following:
- a. Contaminated fluid
  - b. Improper fluid
  - Improper operating procedures
  - c. Cavitation
  - e. Improper pump maintenance

## ANSWERS TO TEST

19. a.  Energy Triangle



20. Performance skills evaluated to the satisfaction of the instructor

## **VALVES UNIT VIII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to select true statements concerning the operations of pressure reducing valves pressure compensated flow control valves, priority flow dividers, and proportional flow dividers, and discuss the operation of a needle valve as a flow control device and the flow paths in a directional control valve controlling a cylinder. The student should also be able to disassemble, inspect, and reassemble a pressure control valve, a flow control valve, and a directional control valve. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to valves with their correct definitions.
2. Name three categories of valves.
3. Name three types of pressure control valves.
4. Name the types of pressure relief valves when given a description of their operations.
5. Select true statements concerning the operation of a pressure reducing valve.
6. List three types of flow control valves.
7. Select true statements concerning the operation of a needle valve as a flow control device.
8. Select true statements concerning the operation of a pressure compensated flow control valve.
9. Select true statements concerning the operation of a priority flow divider.
10. Select true statements concerning the operation of a proportional flow divider.
11. Identify types of directional control valves.
12. Distinguish between the operation of a check valve and a spool direction control valve.



## OBJECTIVE SHEET

13. Discuss the flow paths in a directional control valve controlling a cylinder.
14. Distinguish between open center and closed center systems.
15. Select types of actuators for directional control valves.
16. Identify symbols for hydraulic valves.
17. Demonstrate the ability to:
  - a. Disassemble, inspect, and reassemble a pressure control valve. (Job Sheet #1)
  - b. Disassemble, inspect, and reassemble a directional control valve. (Job Sheet #2)
  - c. Disassemble, inspect, and reassemble a flow control valve. (Job Sheet #3)

## **VALVES UNIT VIII**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Demonstrate and discuss the procedures outlined in the job sheets.
- F. Show students examples of valves.
- G. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Operation of a Pressure Relief Valve
  - 2. TM 2 — Types of Pressure Relief Valves
  - 3. TM 3 — Operation of a Pressure Reducing Valve
  - 4. TM 4 — Operation of Flow Control Valves
  - 5. TM 5 — Types of Directional Control Valves
  - 6. TM 6 — Operation of Directional Control Valves
  - 7. TM 7 — Open and Closed Center Spool Valves (In Neutral)
  - 8. TM 8 — Symbols for Hydraulic Valves
- D. Job sheets
  - 1. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Pressure Control Valve
  - 2. Job Sheet #2 — Disassemble, Inspect, and Reassemble a Directional Control Valve
  - 3. Job Sheet #3 — Disassemble, Inspect, and Reassemble a Flow Control Valve.

## CONTENTS OF THIS UNIT

- E. Test
- F. Answers to test

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1967.
- B. *Fluid Power I*. Cleveland, OH 44112: Parker Hannifin Corporation, 1975.

## **VALVES UNIT VIII**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Valve — A device which controls fluid flow directions, pressure, or flow rate
- B. Pressure control valve — A valve whose function is to control pressure
- C. Flow control valve — A valve whose function is to control flow rate
- D. Directional control valve — A valve whose primary function is to direct or prevent flow through selected passages
- E. Relief valve — A valve which is used to limit the maximum pressure in a hydraulic system
- F. Poppet — That part of certain valves which prevents flow when it closes against a seat
- G. Spool — A term loosely applied to almost any moving cylindrically shaped part of a hydraulic component which moves to direct flow through the component
- H. Pilot — An auxiliary valve used to control the operation of another valve; the controlling stage of a 2 stage valve
- I. Feathering — The operation of moving a valve through partial travel in order to get reduced flow rate

#### **II. Categories of valves**

- A. Pressure control
- B. Flow control
- C. Directional control

#### **III. Types of pressure control valves**

- A. Relief valve
  - 1. Simple  
Example: Cartridge valves and bypass valves
  - 2. Compound or pilot operated
- B. Pressure reducing

## INFORMATION SHEET

### IV. Types and operation of pressure relief valves (Transparency 1)

#### A. Simple (Transparency 2)

1. A spring holds a poppet against a seat
2. When the pressure in the system is large enough to overcome the spring force, the poppet moves off of the seat to allow fluid flow to the bypass
3. The spring tension is set so that the poppet opens to divert sufficient flow from the rest of the system and limit the pressure to a specified value

(NOTE: It is important to remember that pressure and flow in a hydraulic system are directly related.)

#### B. Compound (Transparency 2)

1. A spring holds the main stage spool so that the discharge port is normally blocked
2. A small amount of fluid flows past the main stage spool through a passage to another valve which is also part of the relief valve

(NOTE: This valve is known as the pilot valve.)

3. The pressure of the fluid emitted to the pilot valve creates a force on the pilot valve poppet
4. If this force is greater than the spring force then the poppet moves off its seat thus allowing a small amount of fluid to flow out the drain
5. The pressure resulting from flow past the pilot valve poppet is applied to the back side of the main stage spool
6. This pressure force on the spool plus the main stage spring force must be overcome by the system pressure on the front side of the main stage spool before this spool moves off its seat to allow flow to the discharge

(NOTE: Remember that  $\text{force} = \text{pressure} \times \text{area}$ .)

7. In operation, the tension of the pilot stage spring is adjusted so that the main stage spool opens at some specified pressure

(NOTE: Although the compound relief valve is more complex than a simple relief valve, it is often used because it does a better job of limiting the system pressure to a specified value.)

## INFORMATION SHEET

### C. Pilot operated

1. The operation is similar to a compound relief valve except the pilot stage is not part of the relief valve package
2. A separate pilot valve in a remote location is used to adjust relief valve pressure

### V. Operation of a pressure reducing valve (Transparency 3)

- A. A pressure reducing valve controls the pressure in a secondary circuit to a specified value, and when the pressure in this circuit is low, the spool is fully open
- B. The secondary circuit pressure acts on one side of the spool, and when the pressure is great enough to move the spool against the spring, the flow passage from the main to the secondary circuit is restricted
- C. This operation will tend to regulate the pressure in the secondary as long as the main circuit pressure is greater than the desired secondary circuit pressure
- D. The secondary circuit pressure can be adjusted by adjusting the spring tension

(NOTE: Only constant reduced pressure valves have been discussed. Some pressure reducing valves provide a fixed amount of pressure reduction (such as 500 PSI) across a valve. The operation of this valve is similar, except secondary circuit pressure is applied to both sides of the spool.)

### VI. Types of flow control valves

- A. Needle valve  
(NOTE: This is also called a simple restrictor.)
- B. Compensated flow control valve
- C. Flow divider

### VII. Operation of a needle valve as a flow control device (Transparency 4)

- A. A needle valve serves as an adjustable means of regulating the flow to a secondary circuit (such as a motor or a cylinder) by restricting the fluid flow
- B. As the knob on the needle valve is turned a needle is lowered into the fluid stream
- C. With the knob turned to its extreme position the needle closes onto a seat restricting the fluid flow

(NOTE: A needle valve is considered an uncompensated flow control device because flow will increase if the inlet pressure increases.)

## INFORMATION SHEET

### VIII. Operation of a pressure compensated flow control valve (Transparency 4)

- A. Flow through a fixed orifice in the inlet causes a pressure drop
- B. The full inlet pressure is applied to the inlet side and a reduced pressure is applied to the spring side of the spool
- C. If the force created by the pressure differences is greater than the spring force, the valve spool moves to close the outlet orifice and thus reduce the flow rate
- D. The system functions to maintain a constant pressure drop across the inlet orifice, and if this pressure is controlled, then the flow will be controlled
- E. The flow may be varied by varying the spring tension

### IX. Operation of a priority flow divider (Transparency 4)

- A. A priority flow divider functions to supply a regulated flow to the priority output, and the remaining flow is routed to the secondary circuit
- B. As the flow divider spool slides in its bore, one outlet is opened wider when the other is closed off
- C. Fluid from the inlet is metered through an orifice in the spool, causing a pressure drop which tends to displace the spool to close off the priority outlet, and this displacement is resisted by the spring
- D. The spool will position to maintain a constant pressure drop across the spool orifice and thus a constant flow to the priority outlet
- E. The secondary outlet will be opened to receive the remaining flow that is available

(NOTE: A priority flow divider is used in circuits where flow must be maintained to some part of the circuit. A common example is when a single pump is both used to supply steering and used to insure that a constant flow rate, say 2 GPM, to the steering. Any remaining flow is then available to the auxiliary circuits.)

### X. Operation of a proportional flow divider (Transparency 4)

- A. A proportional flow divider is used to divide the flow into two circuits
- B. Fluid from the inlet flows through two orifices (one on each side of the spool) causing a pressure drop across the two orifices; the resulting pressure is applied to each side of the spool
- C. If the pressure drop across the two orifices is not equal the spool shifts and changes the restriction at the outlet orifice
- D. The valve functions to maintain equal pressure drop across the inlet orifices

(NOTE: The ratio of the flow from the two outlets is set by the size of the two inlet orifices. Equal orifice sizes result in equal flow rates.)

## INFORMATION SHEET

### **XI. Types of directional control valves (Transparency 5)**

- A. Check valve
- B. Rotary valve
- C. Spool valve

### **XII. Operation of a check valve and a spool direction control valve (Transparency 6)**

- A. Check valve
  - 1. Only allows fluid to flow in one direction, from inlet to outlet
  - 2. When pressure is applied to the inlet, it causes the valve to open against the spring allowing flow to pass
  - 3. When pressure is applied to the outlet side of the check valve, the valve is held firmly against its seat thus blocking fluid flow in this direction
- B. Spool direction control valve
  - 1. A directional control valve serves to "direct" the fluid from a pump to an actuator such as a motor or cylinder
  - 2. Lands on spool are used to open or close openings to passages in the valve body

### **XIII. Flow paths in a directional control valve controlling a cylinder (Transparency 6)**

- A. Valve shifted to extend cylinder
  - 1. The handle is moved to the left and the lands open flow passages from the pump to the head side of the cylinder
  - 2. A flow passage from the rod side of the cylinder is opened to route this flow to the reservoir
- B. Valve shifted to retract the cylinder
  - 1. The valve is moved to the right and lands open flow passages from the pump to the rod side of the cylinder
  - 2. A flow passage from the head side of the cylinder is opened to route this to the reservoir



## INFORMATION SHEET

### **XIV. Fluid flow in directional control valves in the neutral position (Transparency 7)**

#### **A. Open center**

1. These valves have lands which direct the pump to the reservoir when the valve is in the neutral position
2. The lands may be positioned on the spool to block flow from both sides of the cylinder (as shown in Transparency 8) or allow flow to pass from one side to the other side of the cylinder

(NOTE: These are called open center valves. These are used with fixed displacement pumps (constant flow pumps). Such systems are called open center systems.)

#### **B. Closed center**

1. The lands are positioned on the spool to block flow from the pump when the valve is in the neutral position
2. The lands may be positioned on the spool to block flow from both sides of the cylinder, or allow flow to pass from one side to the other side of the cylinder

### **XV. Types of actuators for directional control valves**

#### **A. Hand lever**

#### **B. Electrical solenoid**

(NOTE: This allows an electric signal to shift the valve to either extreme.)

#### **C. Servo valve**

(NOTE: This allows an electric signal to shift the valve to various intermediate positions.)

#### **D. Pilot operated**

(NOTE: This allows hydraulic pressure to shift the valve.)

### **XVI. Symbols for hydraulic valves (Transparency 8)**

#### **A. Pressure control**

1. Relief valve
2. Pressure reducing valve

## INFORMATION SHEET

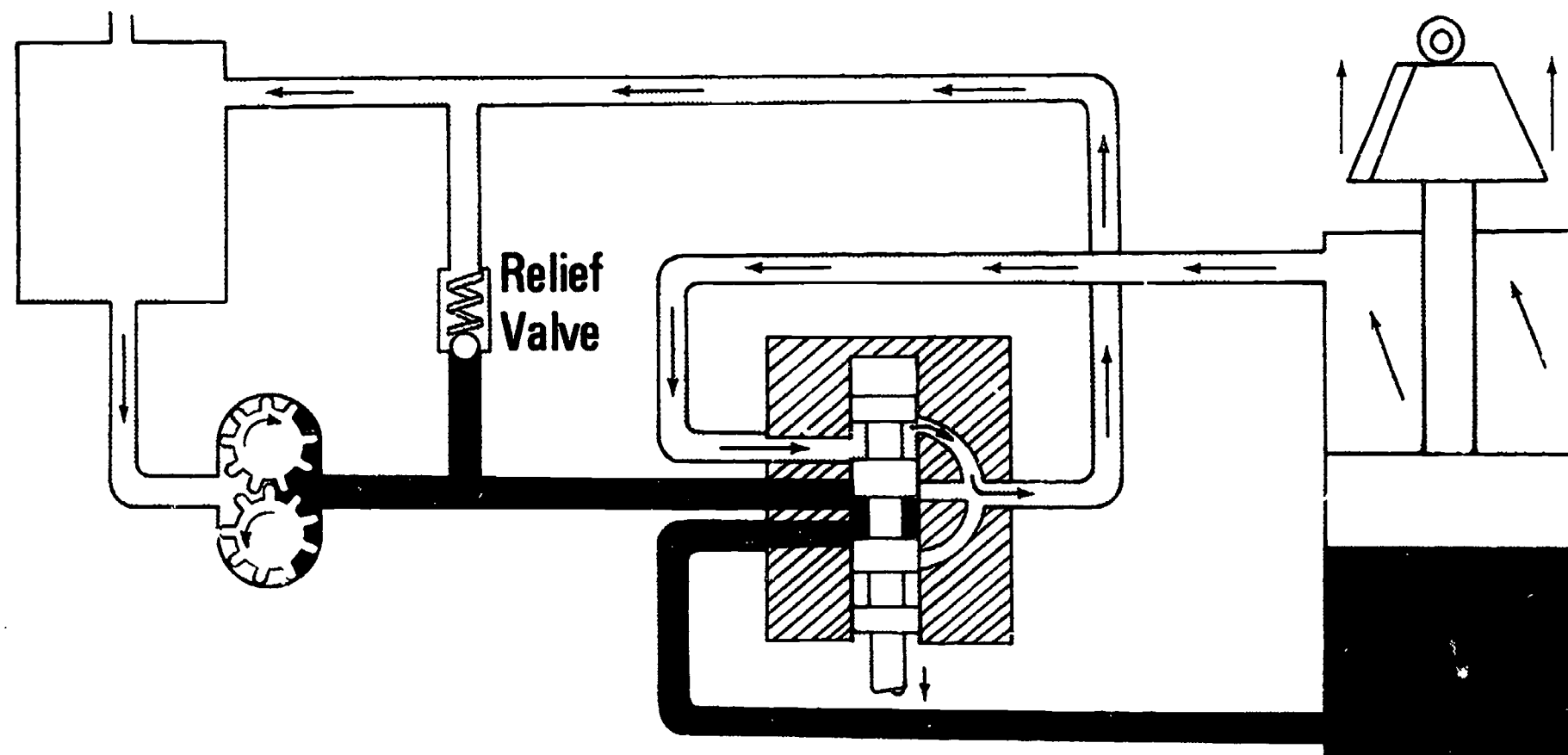
### B. Flow control

1. Restrictor
2. Pressure compensated flow control

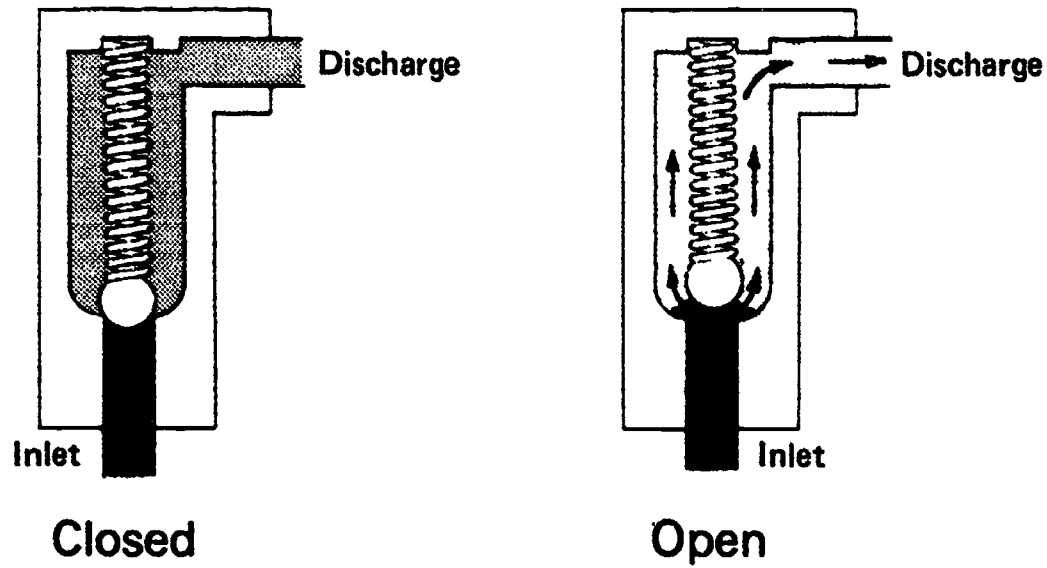
### C. Directional control

1. Check valve
2. Spool valves
  - a. 3 position, 4 way open center
  - b. 3 position, 4 way closed center

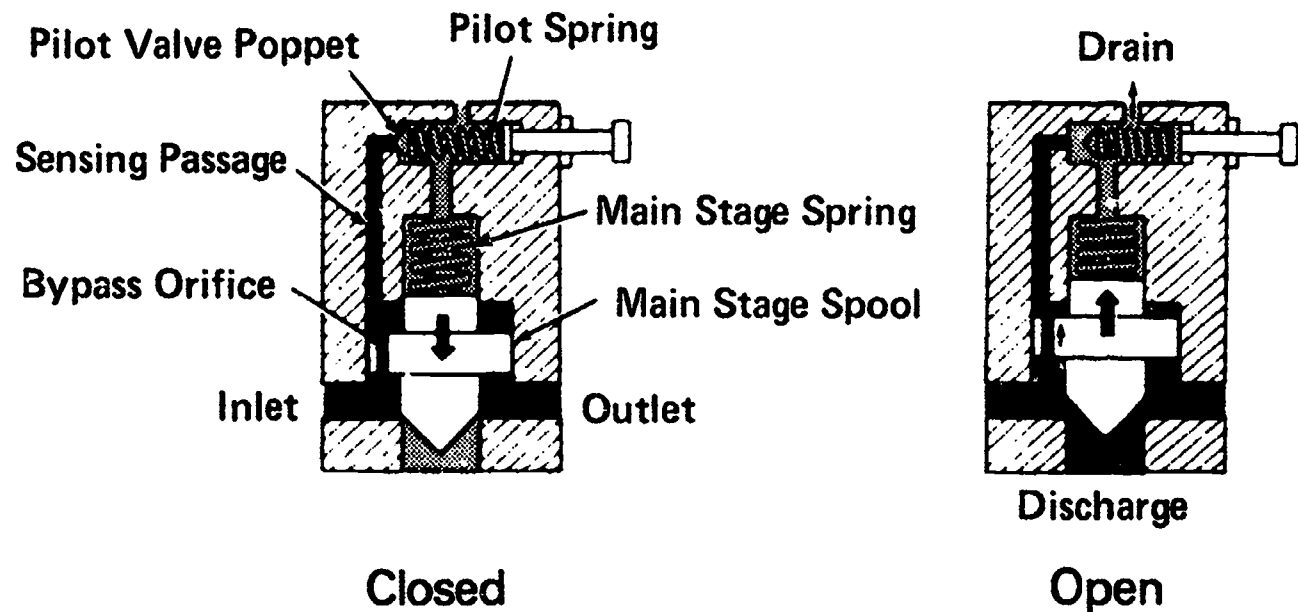
# Operation of a Pressure Relief Valve



# Types of Pressure Relief Valves

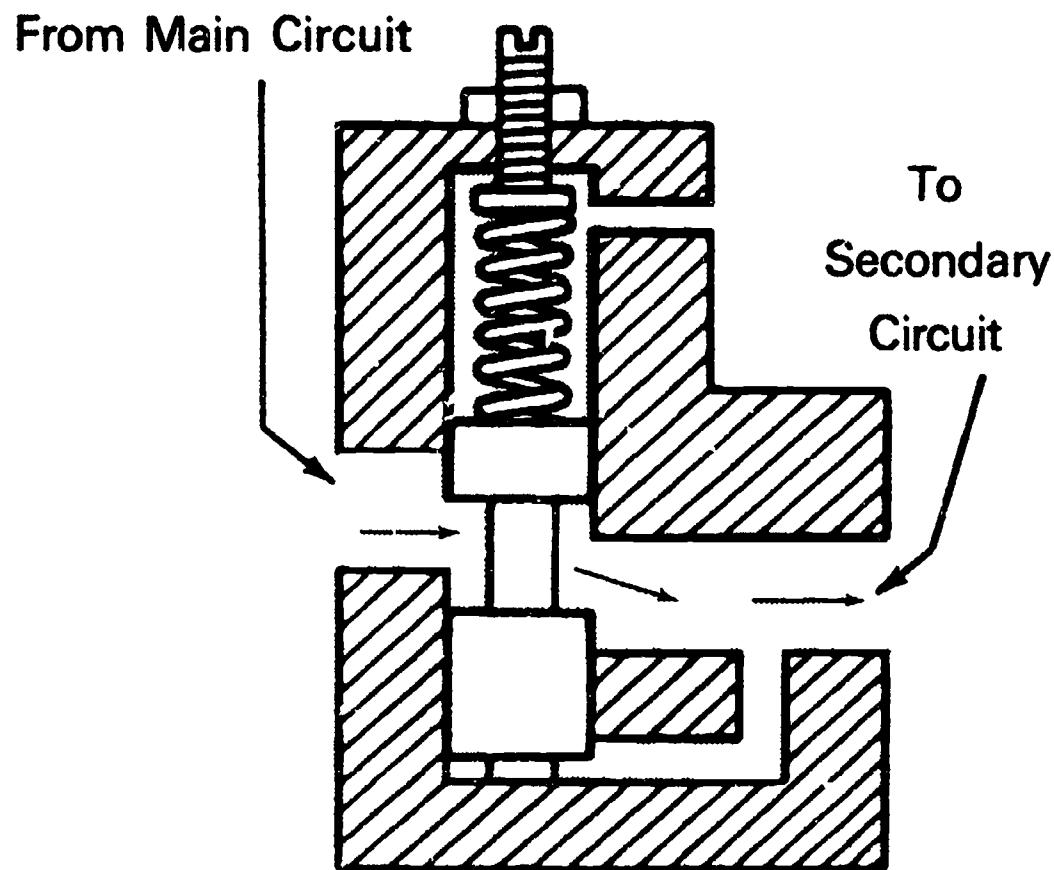


## Simple

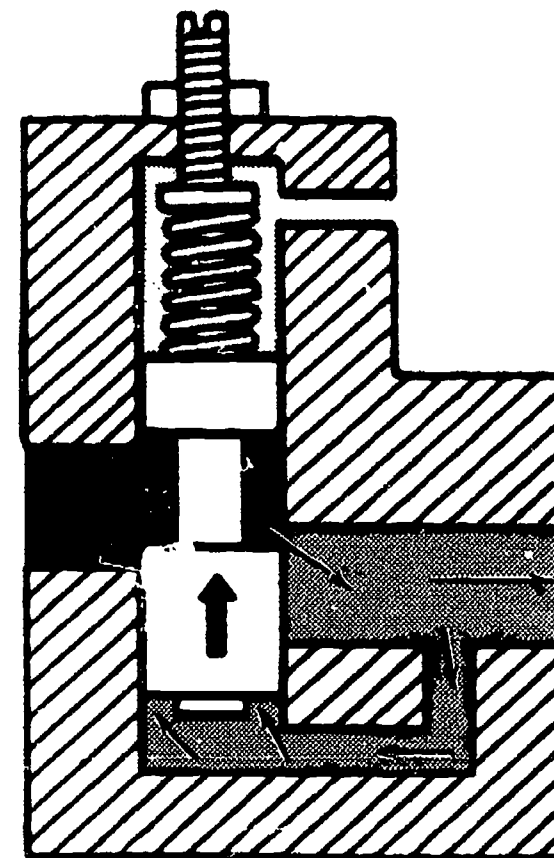


## Compound

# Operation of a Pressure Reducing Valve

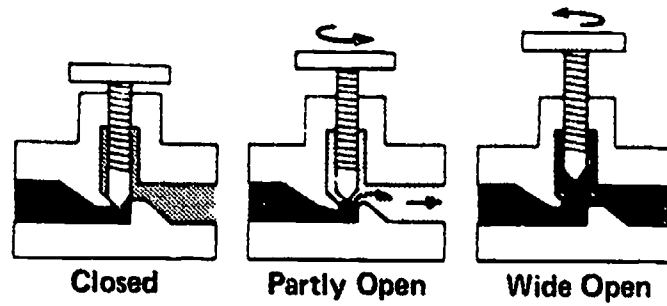


Valve Open,  
Not Operating

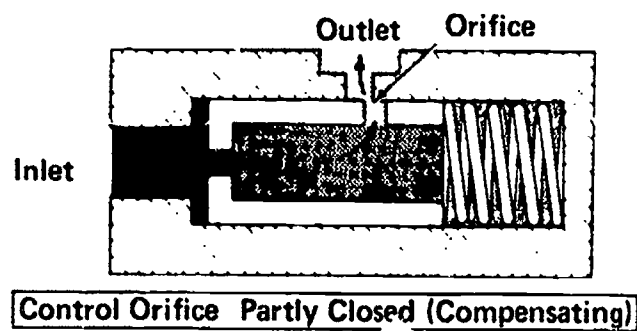
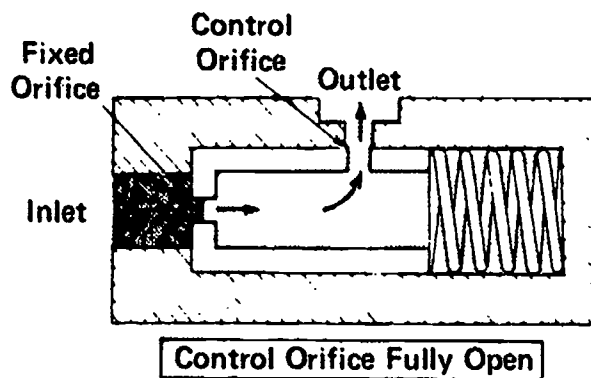


Valve Partly Closes  
to Reduce Pressure

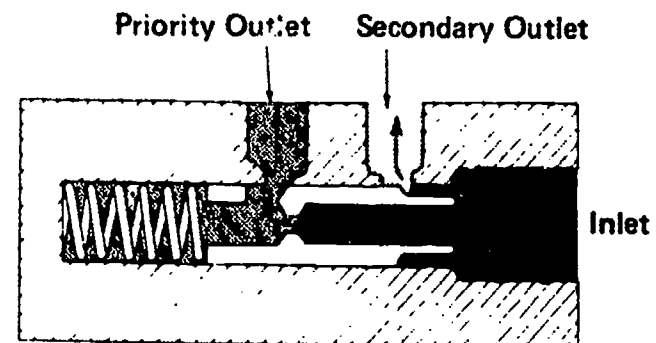
# Operation of Flow Control Valves



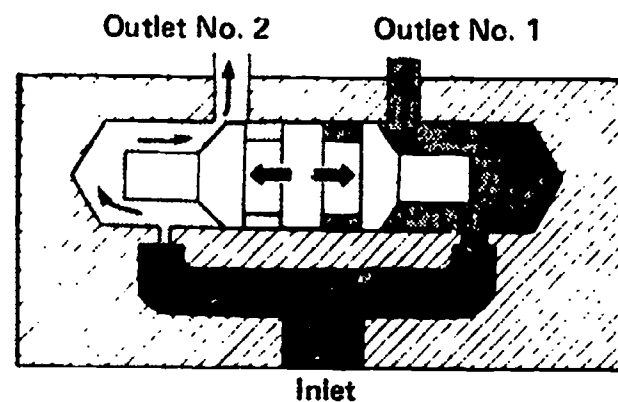
**Needle Valve**



**Pressure Compensated  
Flow Control Valve**

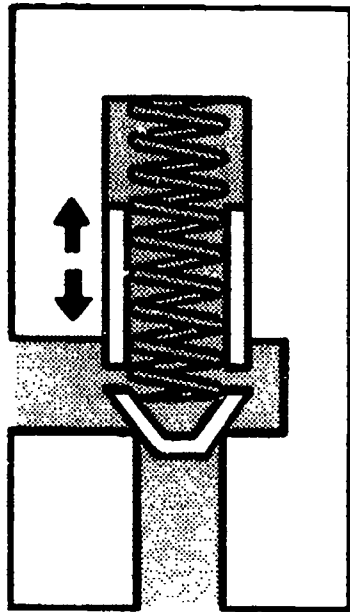


**Priority Flow Divider**

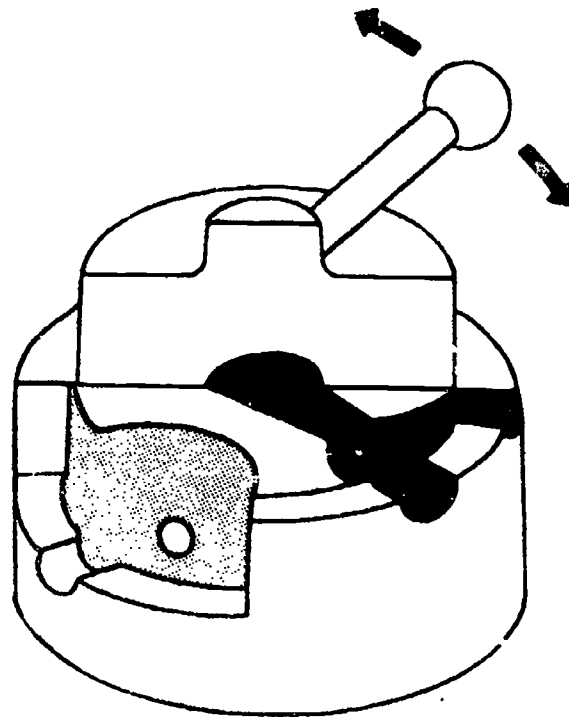


**Proportional Flow Divider**

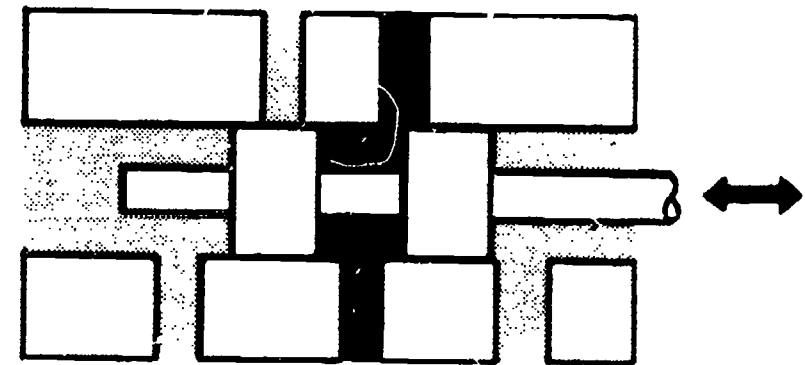
# Types of Directional Control Valves



Check Valve

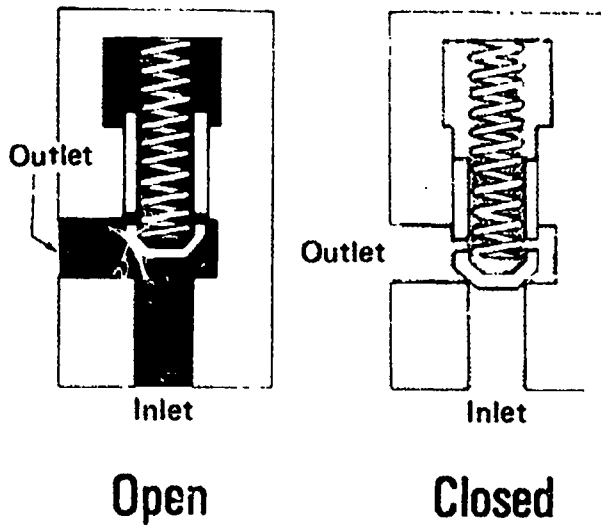


Rotary Valve

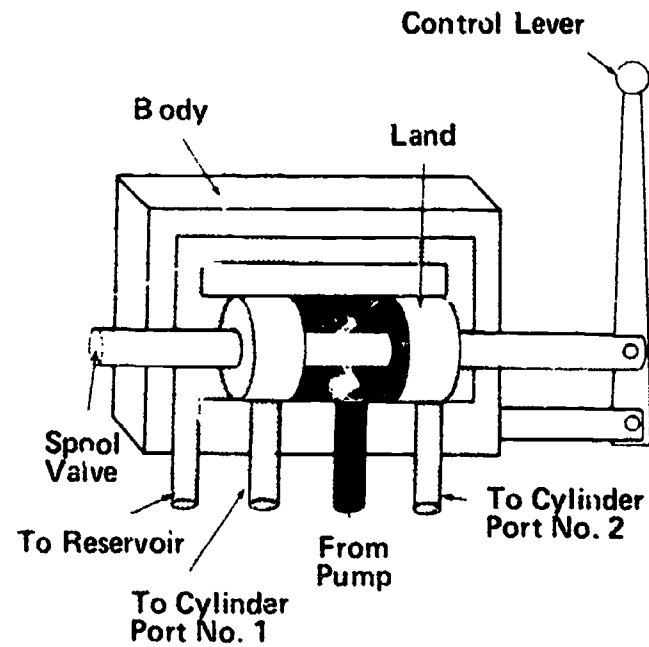


Spool Valve

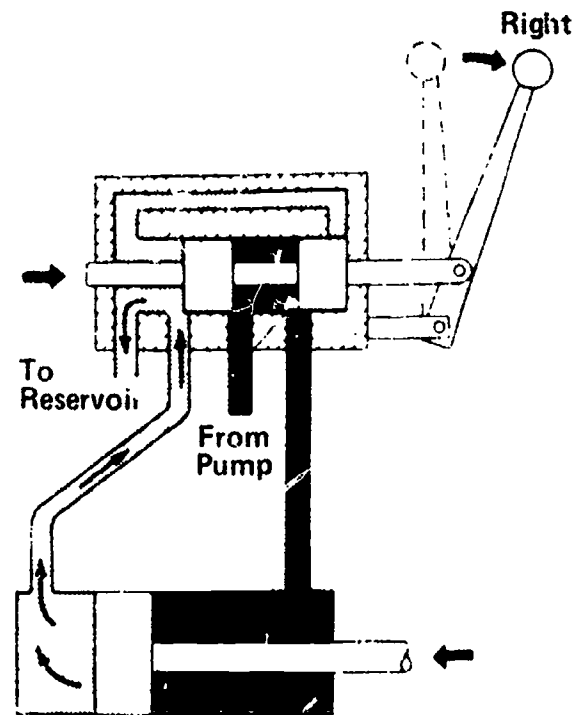
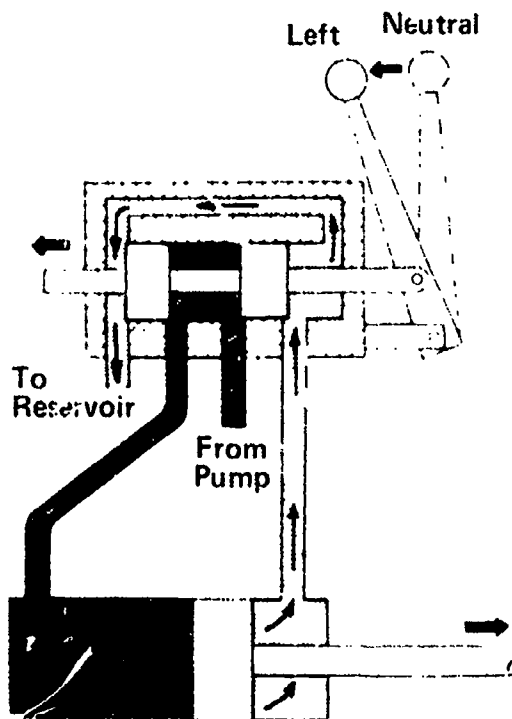
# Operation of Directional Control Valves



Check Valve  
In Operation



Spool Directional Valve

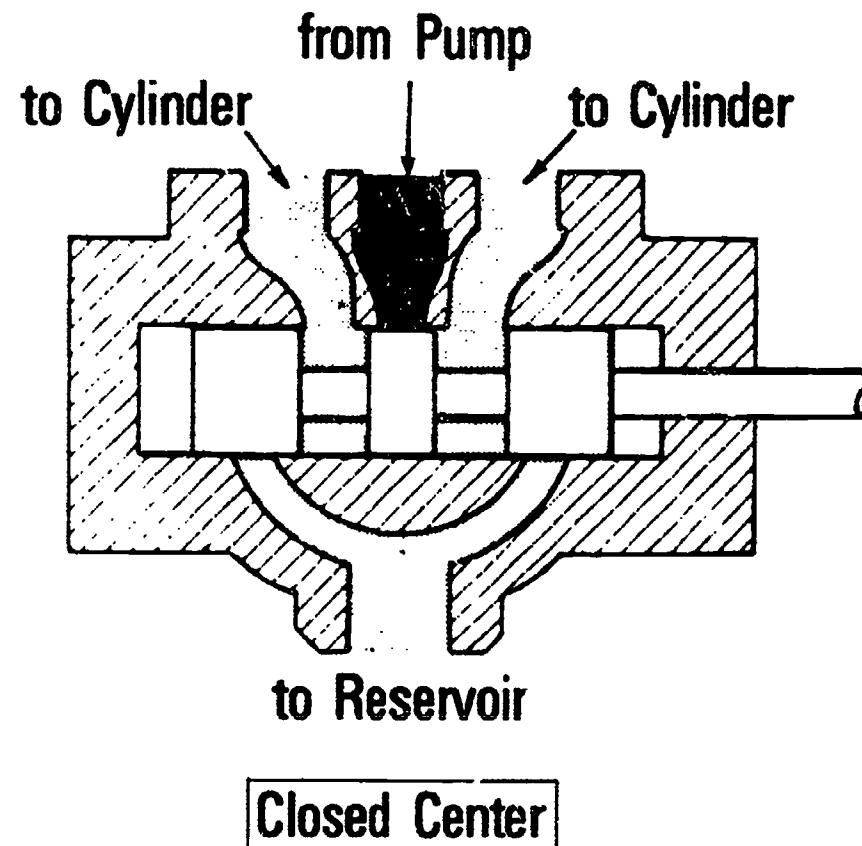
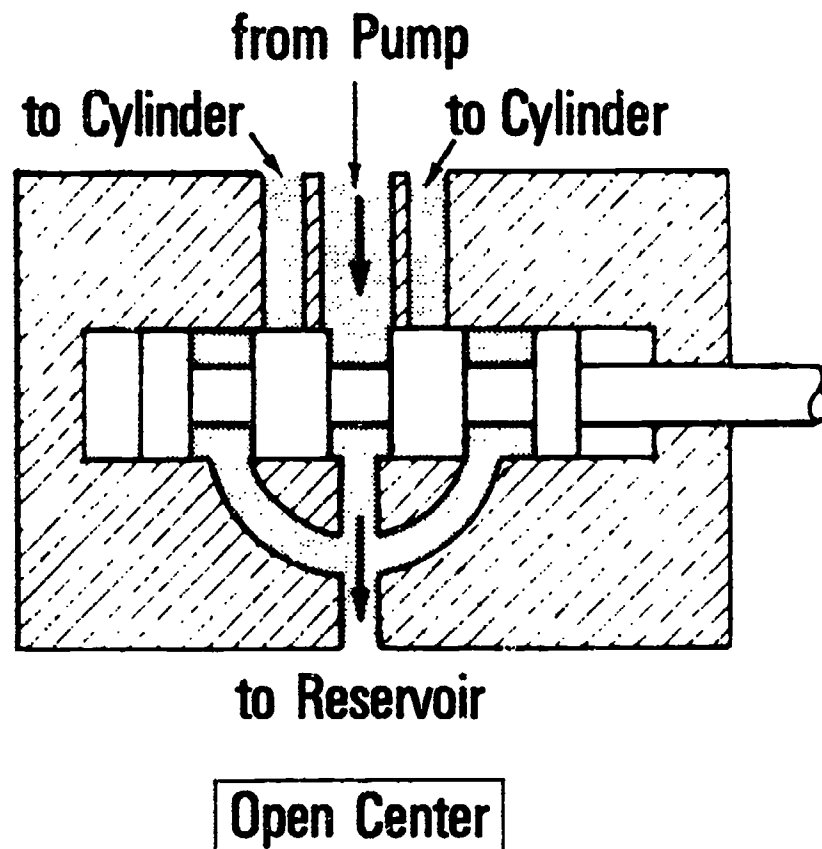


Spool Valve Directing Oil to Cylinder



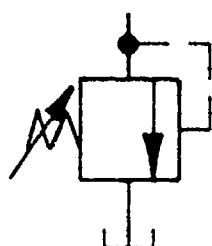
# Open and Closed Center Spool Valves

(In Neutral)

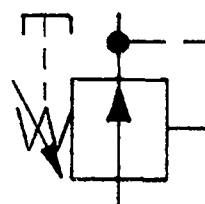


# Symbols for Hydraulic Valves

## Pressure Control



Relief Valve



Pressure Reducing Valve

## Flow Control

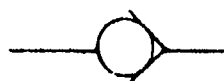


Restrictor

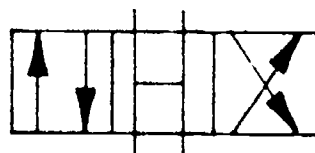


Pressure Compensated  
Flow Control

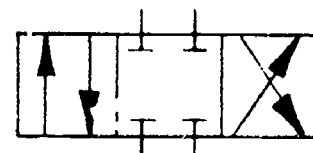
## Directional Control



Check Valve



3 Position, 4 Way  
Open Center  
Spool Valve



3 Position, 4 Way  
Closed Center  
Spool Valve

## VALVES UNIT VIII

### JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE CONTROL VALVE

**A. Tools and materials**

1. Pressure control valve
2. Service manual (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

**B. Routine #1 — Disassemble the valve**

1. Remove the valve adjuster screw
2. Remove the valve spring
3. Remove the valve spool or poppet
4. If the valve is a compound valve remove the main stage spring and spool

☐ Have your instructor check your work

**C. Routine #2 — Inspect the valve**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Inspect the spool(s) or poppet and body for unusual wear		
2. Inspect any O-ring seals for nicks and breaks, and replace if necessary		
3. Inspect internal fluid passages then clean with solvent		

☐ Have your instructor check your work

**JOB SHEET #1****D. Routine #3 — Reassemble the valve**

(NOTE: Lube components prior to reassembly.)

1. Install main stage spool and spring if compound valve
2. Install poppet or spool
3. Install spring
4. Replace adjustor screw and tighten only partially into valve body
- ☐ Have your instructor check your work
5. Clean up area and return tools and materials to proper storage

## VALVES UNIT VIII

### JOB SHEET #2 — DISASSEMBLE, INSPECT, AND REASSEMBLE A DIRECTIONAL CONTROL VALVE

**A. Tools and materials**

1. Directional control valve

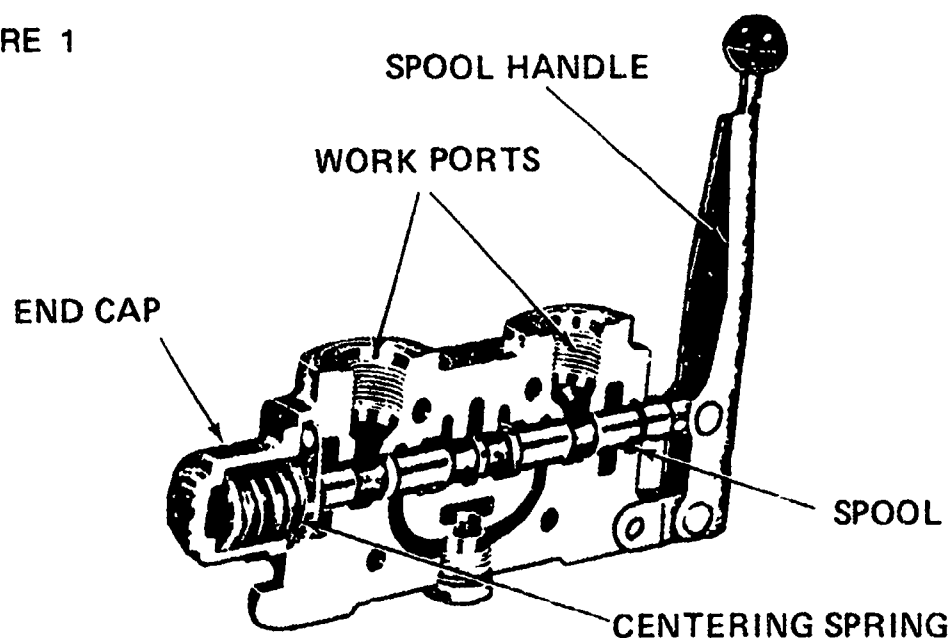
(NOTE: This procedure assumes that a manually operated directional control valve will be used. Other types of directional control valves may be used with minor changes to this procedure.)

2. Service manual if available
3. Hand tools
4. Lint free shop towels
5. Shipping plugs for open ports
6. Safety glasses

**B. Routine #1 — Disassemble the valve**

(NOTE: Figure 1 shows a cut-away view of a typical directional control valve.)

**FIGURE 1**



(NOTE: Be sure spools are replaced into the openings from which they were removed.)

1. Install the shipping plugs into the valve ports
2. Clean the external surfaces of the valve with solvent

## JOB SHEET #2

3. Place the valve in a clean area for disassembly
4. Remove the spool handle if not already removed
5. Remove the end cap
6. Remove the nut that holds the centering spring and remove spring
7. Carefully slide the spool from the valve body

☐ Have your instructor check your work

**C. Routine #2 — Inspect the valve**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine the spool for excessive wear  (NOTE: The lands on the spool may become eroded from forces resulting from the fluid flow. Wear can also occur from contaminated fluid.)		
2. Examine the spool O-ring seals, and replace if worn or nicked		
3. Examine the valve body for cracks		

☐ Have your instructor check your work

**D. Routine #3 — Reassemble the valve**

(NOTE: Lubricate all components during reassembly.)

1. Carefully install the spool into the valve body, and use special care to insure that the O-rings are not damaged during installation
2. Install the centering spring and washers (if used) and retaining nut
3. Tighten nut
4. Install end cap
5. Install spool handle

☐ Have your instructor check your work

6. Clean up area and return tools and materials to proper storage

## VALVES UNIT VIII

### JOB SHEET #3 — DISASSEMBLE, INSPECT, AND REASSEMBLE A FLOW CONTROL VALVE

**A. Tools and materials**

1. Flow control valve
2. Service manual (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses
7. Shipping plugs

**B. Routine #1 — Disassemble the valve**

1. Place shipping plugs into the valve ports
2. Clean the external surfaces
3. Place the valve on a clean surface for disassembly
4. Remove the spring retainer cap
5. Remove the spring and spool

☐ Have your instructor check your work

**C. Routine #2 — Inspect the valve**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine any O-ring seals, and replace		
2. Inspect spool for excessive wear		
3. Inspect spool body for unusual wear		

☐ Have your instructor check your work

**JOB SHEET #3****D. Routine #3 — Reassemble the valve**

(NOTE: Lubricate all parts during reassembly.)

1. Clean all internal surfaces with the solvent
2. Install the spool taking care not to damage the O-ring seals
3. Install the spring
4. Replace the spring retainer cap
- ☐ Have your instructor check your work
5. Clean up area and return tools and materials to proper storage



# VALVES

## UNIT VIII

NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with the correct definitions.

- |         |   |                              |
|---------|---|------------------------------|
| _____a. | A valve whose primary function is to direct or prevent flow through selected passages   | 1. Poppet                    |
| _____b. | A term loosely applied to almost any moving cylindrically shaped part of a hydraulic component which moves to direct flow through the component | 2. Pressure control valve    |
| _____c. | A valve whose function is to control pressure   | 3. Spool                     |
| _____d. | An auxiliary valve used to control the operation of another valve; the controlling stage of a 2-stage valve                                     | 4. Directional control valve |
| _____e. | A device which controls fluid flow directions, pressure, or flow rate   | 5. Feathering                |
| _____f. | A valve whose function is to control flow rate  | 6. Flow control valve        |
| _____g. | That part of certain valves which prevents flow when it closes against a seat   | 7. Relief valve              |
| _____h. | A valve which is used to limit the maximum pressure in a hydraulic system   | 8. Pilot                     |
| _____i. | The operation of moving a valve through partial travel in order to get reduced flow rate  | 9. Valve                     |

2. Name three categories of valves.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

## TEST

3. Name three types of pressure control valves.

- a. \_\_\_\_\_
- 1) \_\_\_\_\_
- 2) \_\_\_\_\_
- b. \_\_\_\_\_

4. Name the types of pressure relief valves for the following operations:

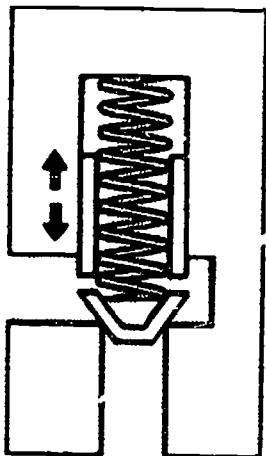
- a. \_\_\_\_\_
- 1) The operation is similar to a compound relief valve except the pilot stage is not part of the relief valve package
- 2) A separate pilot valve in a remote location is used to adjust relief valve pressure
- b. \_\_\_\_\_
- 1) A spring holds a poppet against a seat
- 2) When the pressure in the system is large enough to overcome the spring force, the poppet moves off of the seat to allow fluid flow to the bypass
- 3) The spring tension is set so that the poppet opens to divert sufficient flow from the rest of the system and limit the pressure to a specified value
- c. \_\_\_\_\_
- 1) A spring holds the main stage spool so that the discharge port is normally blocked
- 2) A small amount of fluid flows past the main stage spool through a passage to another valve which is also part of the relief valve
- 3) The pressure of the fluid emitted to the pilot valve creates a force on the pilot valve poppet
- 4) If this force is greater than the spring force then the poppet moves off its seat thus allowing a small amount of fluid to flow out the drain
- 5) The pressure resulting from flow past the pilot valve poppet is applied to the back side of the main stage spool
- 6) This pressure force on the spool plus the main stage spring force must be overcome by the system pressure on the front side of the main stage spool before the spool moves off its seat to allow flow to the discharge
- 7) In operation, the tension on the pilot stage spring is adjusted so that the main stage spool opens at some specified pressure

**TEST**

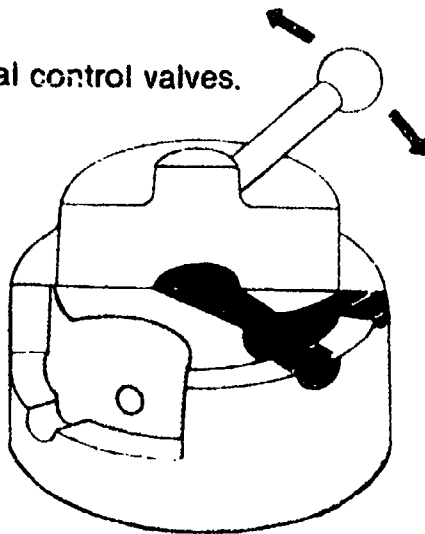
5. Select true statements concerning the operation of a pressure reducing valve by placing an "X" in the appropriate blanks.
- \_\_\_\_\_a. A pressure reducing valve controls the pressure in a secondary circuit to a specified value, and when the pressure in this circuit is low, the spool is fully open
  - \_\_\_\_\_b. The secondary circuit pressure acts on both sides of the spool, and when this pressure is great enough to move the spool against the spring, the flow passage from the main to the secondary circuit is completely open
  - \_\_\_\_\_c. The secondary circuit pressure can be adjusted by adjusting the spring tension
6. List three types of flow control valves.
- a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
7. Select true statements concerning the operation of a needle valve as a flow control device by placing an "X" in the appropriate blanks.
- \_\_\_\_\_a. A needle valve serves as an adjustable means of regulating the flow to a secondary circuit by restricting the fluid flow
  - \_\_\_\_\_b. As the knob on the needle valve is turned a needle is lowered into the fluid stream
  - \_\_\_\_\_c. With the knob turned to its extreme position the needle closes onto a seat restricting the fluid flow
8. Select true statements concerning the operation of a pressure compensated flow control valve by placing an "X" in the appropriate blanks.
- \_\_\_\_\_a. Flow through a fixed orifice in the inlet causes a pressure rise
  - \_\_\_\_\_b. The full inlet pressure is applied to the inlet side and a reduced pressure is applied to the spring side of the spool
  - \_\_\_\_\_c. If the force created by the pressure differences is greater than the spring force, the valve spool moves to close the outlet orifice and thus reduce the flow rate
  - \_\_\_\_\_d. The system functions to maintain a constant pressure rise across the inlet orifice, and if this pressure rise is controlled, then the flow will be controlled
  - \_\_\_\_\_e. The flow may be varied by varying the spring tension

## TEST

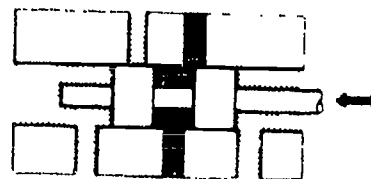
9. Select true statements concerning the operation of a priority flow divider by placing an "X" in the appropriate blanks.
- \_\_\_\_a. A priority flow divider functions to supply a regulated flow to the priority output, and the remaining flow is routed to the secondary circuit
  - \_\_\_\_b. As the flow divider spool slides in its bore, both outlets are opened
  - \_\_\_\_c. Fluid from the inlet is metered through an orifice in the spool, causing a pressure drop which tends to displace the spool to close off the priority outlet, and this displacement is resisted by the spring
  - \_\_\_\_d. The spool will position to maintain a constant pressure drop across the spool orifice and thus a constant flow to the priority outlet
  - \_\_\_\_e. The primary outlet will be opened to receive the remaining flow that is available
10. Select true statements concerning the operation of a proportional flow divider by placing an "X" in the appropriate blanks.
- \_\_\_\_a. A proportional flow divider is used to divide the flow into three circuits
  - \_\_\_\_b. Fluid from the inlet flows through two orifices causing a pressure drop across the two orifices; the resulting pressure is applied to each side of the spool
  - \_\_\_\_c. If the pressure drop across the two orifices is not equal the spool shifts and changes the restriction at the outlet orifice
  - \_\_\_\_d. The valve functions so that inlet orifices have an unequal pressure drop across them
11. Identify the types of directional control valves.



a. \_\_\_\_\_



b. \_\_\_\_\_



c. \_\_\_\_\_

## TEST

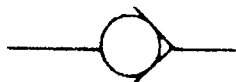
12. Distinguish between the operation of a check valve and a spool direction control valve by placing an "X" next to the descriptions which apply to the operation of a check valve.
- \_\_\_\_\_a. Serves to "direct" the fluid from a pump to an actuator such as a motor or cylinder
  - \_\_\_\_\_b. When pressure is applied to the inlet, it causes the valve to open against the spring allowing flow to pass
  - \_\_\_\_\_c. Lands on spool are used to open or close openings to passages in the valve body
  - \_\_\_\_\_d. Only allows fluid to flow in one direction, from inlet to outlet
  - \_\_\_\_\_e. When pressure is applied to the outlet side, the valve is held firmly against its seat thus blocking fluid flow in this direction
13. Discuss the flow paths in a directional control valve controlling a cylinder.
- a. Valve shifted to extend cylinder\_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
  - b. Valve shifted to retract the cylinder\_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
  - \_\_\_\_\_
14. Distinguish between open and closed center systems by placing an "O" next to the descriptions which apply to open center systems and a "C" next to descriptions which apply to closed center systems.
- (NOTE: Some descriptions may apply to both systems.)
- \_\_\_\_\_a. The lands may be positioned on the spool to block the flow from both sides of the cylinder, or allow flow to pass from one side to the other side of the cylinder
  - \_\_\_\_\_b. The lands are positioned on the spool to block flow from the pump when the valve is in the neutral position
  - \_\_\_\_\_c. These valves have lands which direct the pump to the reservoir when the valve is in the neutral position

# TEST

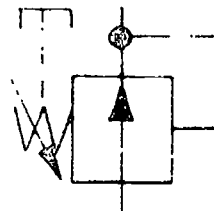
15. Select types of actuators for directional control valves by placing an "X" in the appropriate blanks.

- \_\_\_\_\_a. Hand lever  
 \_\_\_\_\_b. Electrical solenoid  
 \_\_\_\_\_c. Relief valve  
 \_\_\_\_\_d. Servo valve  
 \_\_\_\_\_e. Open center valve  
 \_\_\_\_\_f. Pilot operated

16. Identify the symbols for hydraulic valves.



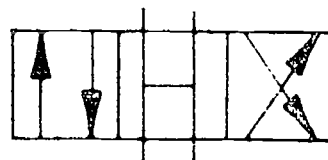
a. \_\_\_\_\_



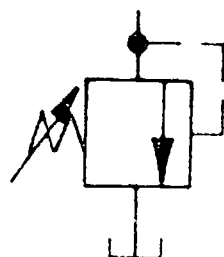
b. \_\_\_\_\_



c. \_\_\_\_\_



d. \_\_\_\_\_

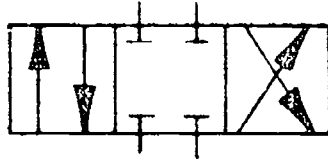


e. \_\_\_\_\_



f. \_\_\_\_\_

## TEST



9. \_\_\_\_\_

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

17. Demonstrate the ability to:

- a. Disassemble, inspect, and reassemble a pressure control valve.
- b. Disassemble, inspect, and reassemble a directional control valve.
- c. Disassemble, inspect, and reassemble a flow control valve.

## VALVES UNIT VIII

### ANSWERS TO TEST

1.   a.    4                   e.    9                   i.    5  
      b.    3                   f.    6  
      c.    2                   g.    1  
      d.    8                   h.    7
2.   a.    Pressure control  
      b.    Flow control  
      c.    Directional control
3.   a.    Relief valve  
          1)   Simple  
          2)   Compound or pilot operated  
      b.    Pressure reducing
4.   a.    Pilot operated  
      b.    Simple  
      c.    Compound
5.   a. c
6.   a.    Needle valve  
      b.    Compensated flow control valve  
      c.    Flow divider
7.   a. b. c
8.   b. c. e
9.   a. c. d
10.  b. c
11.  a.    Check valve  
      b.    Rotary valve  
      c.    Spool valve
12.  b. d. e
13.  Discussion should include:
  - a.    Valve shifted to extend cylinder
    - 1)    The handle is moved to the left and the lands open flow passages from the pump to the head side of the cylinder
    - 2)    A flow passage from the rod side of the cylinder is opened to route this flow to the reservoir



**ANSWERS TO TEST**

- b. Valve shifted to retract the cylinder
  - 1) The valve is moved to the right and lands open flow passages from the pump to the rod side of the cylinder
  - 2) A flow passage from the head side of the cylinder is opened to route this to the reservoir
- 14.
  - a. O, C
  - b. C
  - c. O
- 15. a, b, d, f
- 16.
  - a. Check valve
  - b. Pressure reducing valve
  - c. Restrictor
  - d. 3 position, 4 way open center spool valve
  - e. Relief valve
  - f. Pressure compensated flow control valve
  - g. 3 position, 4 way closed center spool valve
- 17. Performance skills evaluated to the satisfaction of the instructor

## **CYLINDERS**

### **UNIT IX**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to calculate the force output, speed, and power output of a hydraulic cylinder. The student should also be able to disassemble, inspect, and reassemble a hydraulic cylinder and test a hydraulic cylinder for internal and external leakage. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to cylinders with their correct definitions.
2. Discuss the operation of a hydraulic cylinder.
3. Distinguish between the operation of single-acting and double-acting cylinders.
4. Identify types of double-acting cylinders.
5. Identify the parts of a single-acting cylinder.
6. Identify the parts of a double-acting cylinder.
7. List sources of common failures of hydraulic cylinders.
8. Given a formula, calculate the force output of a hydraulic cylinder.
9. Given a formula, calculate the speed of a hydraulic cylinder.
10. Given a formula, calculate the power output of a cylinder.
11. Given a formula, calculate the flow rate required to move a cylinder a given distance in a given time.
12. Draw the symbol for a cylinder.
13. Demonstrate the ability to:
  - a. Disassemble, inspect, and reassemble a hydraulic cylinder. (Job Sheet #1)
  - b. Test a cylinder for internal and external leakage. (Job Sheet #2)

## **CYLINDERS UNIT IX**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet
- B. Provide students with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheets.
- G. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Operation of a Hydraulic Cylinder
  - 2. TM 2 — Operation of Single and Double-Acting Cylinders
  - 3. TM 3 — Types of Double-Acting Hydraulic Cylinders
  - 4. TM 4 — Single-Acting Cylinder
  - 5. TM 5 — Double-Acting Cylinder
- D. Job sheets
  - 1. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Hydraulic Cylinder
  - 2. Job Sheet #2 — Test a Cylinder for Internal and External Leakage
- E. Test
- F. Answers to test

## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1967.
- B. *Analyzing Hydraulic Systems*. Cleveland, OH 44112: Parker Hannifin Corporation, 1976.
- C. *Fluid Power Designers' Lightning Reference Handbook*. Orange, CA: Paul Munroe Hydraulics, Inc., 1976.
- D. *Fluid Power 2*. Cleveland, OH 44112: Parker Hannifin Corporation, 1975.

## **CYLINDERS UNIT IX**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Cylinder — An actuator which converts hydraulic power into linear mechanical force and motion
- B. Piston area — Area of the cylinder piston
- C. Rod area — Area of the piston rod
- D. Rod side area — Effective area on the rod side of the cylinder; equal to the piston area minus the rod area
- E. Back pressure — Pressure in the return lines caused by flow in these lines

#### **II. Operation of a hydraulic cylinder (Transparency 1)**

- A. Hydraulic oil flows into a chamber of the cylinder, causing the cylinder rod to move
- B. Pressure of the fluid acting on the surface of a piston creates a force on the rod

#### **III. Operation of single and double-acting cylinders (Transparency 2)**

- A. Single-acting
  - 1. Oil flows into only one side of the cylinder
  - 2. The cylinder is retracted by gravity or a spring
- B. Double-acting
  - 1. Oil flows into one side to extend the cylinder
  - 2. The cylinder is retracted by oil flow into the other side of the cylinder

#### **IV. Types of double-acting cylinders (Transparency 3)**

- A. Balanced

(NOTE: A balanced double-acting cylinder has an equal area on both sides of piston.)
- B. Unbalanced

(NOTE: Unbalanced double-acting cylinders have unequal areas on each side of the piston.)

## INFORMATION SHEET

### V. Parts of a single-acting cylinder (Transparency 4)

- A. Piston
- B. Piston rod
- C. Piston seal
- D. Rod wiper seal
- E. Air vent
- F. Oil inlet
- G. Cylinder housing
- H. Cylinder bore
- I. Mount

### VI. Parts of a double-acting cylinder (Transparency 5)

- A. Piston
- B. Piston rod
- C. Piston seals
- D. Oil ports
- E. End cap
- F. Rod (pressure) seal
- G. Cylinder housing
- H. Cylinder bore
- I. Mount
- J. Wiper seal

### VII. Sources of common failures of hydraulic cylinders

- A. Bent rod
- B. Scored cylinder barrel
- C. Nicked or damaged rod
- D. Leaking piston seal

## INFORMATION SHEET

- E. Leaking rod seal
- F. Defective wiper seal

(NOTE: A defective wiper seal will often cause a leaking piston or rod seal or other problem.)

## VIII. The force output of hydraulic cylinders

- A. Single-acting — Force = Pressure x Piston Area or  $F=PA$**

**Example:** Calculating force when pressure and area are known  
 Pressure = P = 1500 Pounds per Square Inch (PSI)  
 Piston diameter = D = 3.0 inches

(NOTE:  $\pi = 3.14$ )

**Piston area =  $A = \pi D^2/4 = 3.14(3)^2/4 = 7.07$  sq. in.**

$$\text{Force} = F = 1500 \text{ lbs./sq. in.} \times 7.07 \text{ sq. in.} = 10,600 \text{ lbs.}$$

**Example: Calculating pressure when force and diameter are known**

Force = 5,000 lbs.  
Piston Diameter = 2.0 inches

$$\text{Piston area} = A = \pi D^2/4 = 3.14 \left(\frac{2^2}{4}\right) = 3.14 \text{ sq. in.}$$

$$\text{Pressure} = P = \frac{F}{A} = \frac{5,000}{3.14 \text{ sq. in.}} = 1590 \text{ PSI}$$

- B. Double-acting — Force = Piston Area × Piston Pressure**  
**Rod side Area × Rod side Pressure**

**Example:** Piston diameter = 4 inches  
Rod diameter = 2 inches  
Piston pressure = 1500 Pounds per Square Inch (PSI)  
Rod-side pressure = 500 Pounds per Square Inch (PSI)

**Piston area =  $\pi D^2/4 = 3.14 (4)^2/4 = 12.6$  sq. in.**

Rod area =  $(3.14) (2)^2/4 = 3.14$  sq. in.  
Rod-side area =  $12.56 - 3.14 = 9.42$  sq. in.

$$F = (1500 \frac{\text{lbs.}}{\text{sq. in.}}) \times (12.6 \text{ sq. in.}) - (500 \frac{\text{lbs.}}{\text{sq. in.}}) (9.42 \text{ sq. in.})$$

$$F = 14,190 \text{ lbs.}$$

## INFORMATION SHEET

### IX. Formulas for speed of a cylinder

#### A. Single-acting —

$$\text{Rod speed} = \frac{\text{flow rate} \times 19.25}{\text{Piston Area}} \text{ or } V = \frac{Q \times 19.25}{A}$$

(NOTE: This equation requires that the unit of measure of flow rate be GAL/MIN (GPM) and unit of measure of piston area be square inches. The rod speed will be in feet per minute.)

Example: Flow rate into cylinder =  $Q = 5\text{ GPM}$   
Piston Diameter =  $D = 3$

Then: Piston Area =  $3.14 (3)^2/4 = 7.07 \text{ sq. in.}$

$$V = \frac{Q \times 19.25}{A} = \frac{5 \text{ Gal/Min} \times 19.25}{7.07 \text{ sq. in.}} = 13.6 \text{ ft/min.}$$

#### B. Double-acting —

$$\text{Rod speed} = \frac{\text{flow rate} \times 19.25}{\text{Area}} \text{ or } V = \frac{Q \times 19.25}{A}$$

where the area is the piston area when the rod is extending and the rod-side area when the piston is retracting

Example:

Piston diameter = 4 inches  
Rod diameter = 2 inches  
Piston area = 12.6 sq. in.  
Rod area = 3.14 sq. in.  
Rod-side area = 9.42 sq. in.

If the cylinder is extending and the flow into the piston side is 10 GPM, then:

$$V = \frac{10 \text{ GPM} \times 19.25}{12.6 \text{ sq. in.}} = 15.3 \text{ ft/min.}$$

If the cylinder is retracting and the flow into the rod side is 10 GPM, then:

$$V = \frac{10 \text{ GPM} \times 19.25}{9.42 \text{ sq. in.}} = 20.4 \text{ ft/min.}$$



## INFORMATION SHEET

### X. Formula for power output of a cylinder —

$$\text{Power} = \frac{V \times F}{33,000}$$

Where:  $V$  = Rod velocity (ft/sec)  
 $F$  = Rod force (pounds force)  
 Power = Power Out (Horsepower)

Example:

$V = 10$  ft/sec  
 $F = 5000$  pounds force

$$\text{Power} = \frac{(10)(5000)}{33000} = 4.5 \text{ HP}$$

### XI. Formula for the flow rate required to move a cylinder a given distance in a given time —

$$Q = \frac{A \times L}{T \times 231}$$

Where:  $Q$  = Flow rate in gallons per minute (GPM)  
 $A$  = Area in square inches (in<sup>2</sup>)  $L$  = Length in inches (in)  $T$  = Time in minutes

Example:

To move a 2 inch diameter cylinder 20 inches in 0.5 minute the flow rate required is 0.54 GPM.

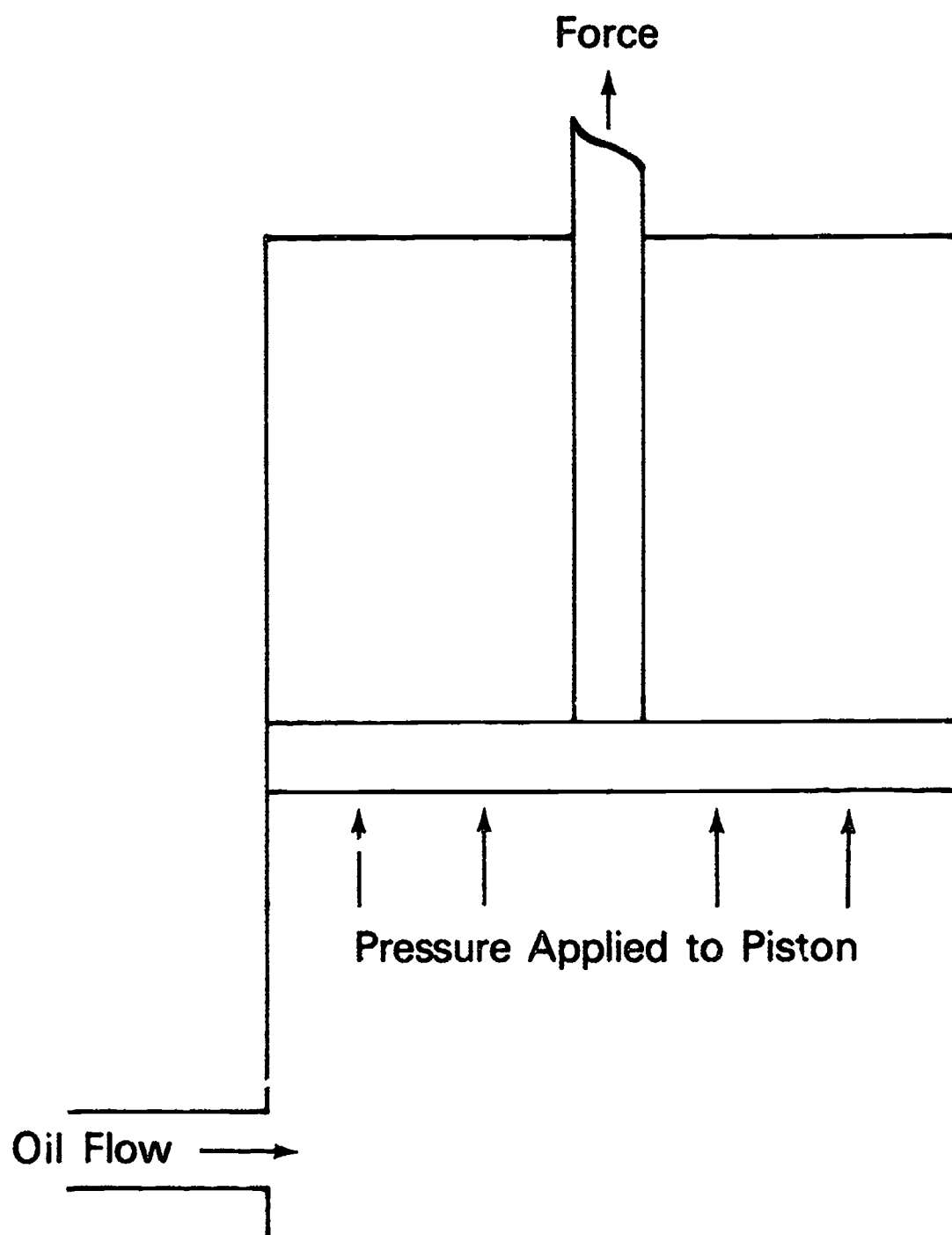
$$A = \frac{\pi D^2}{4} = \frac{3.14(2^2)}{4} = 3.14 \text{ in}^2$$

$$Q = \frac{(3.14) \times 20 \text{ inches}}{0.5 \text{ minutes} \times 231} = 0.54 \text{ GPM}$$

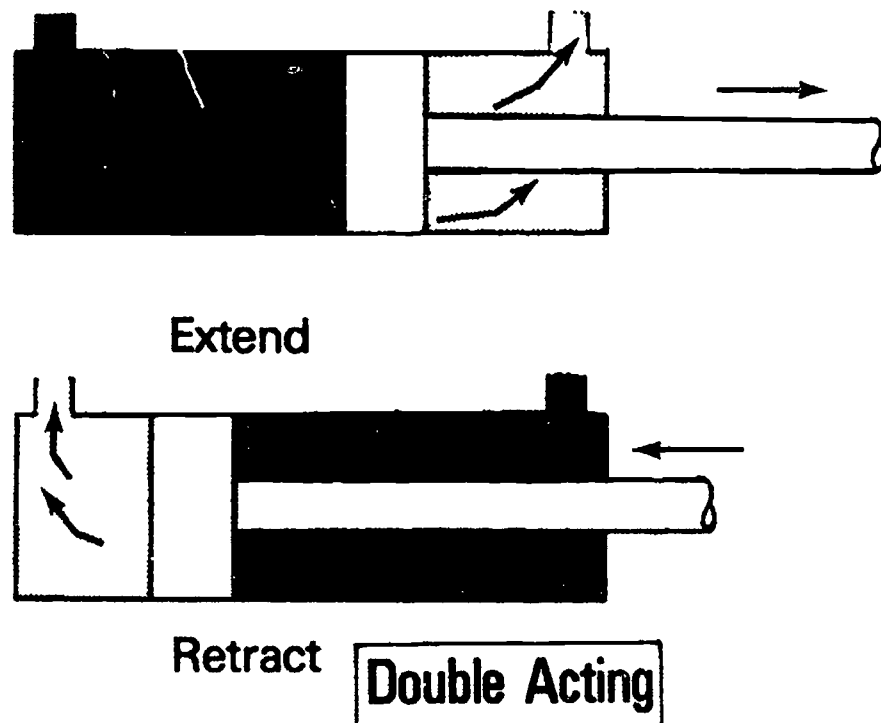
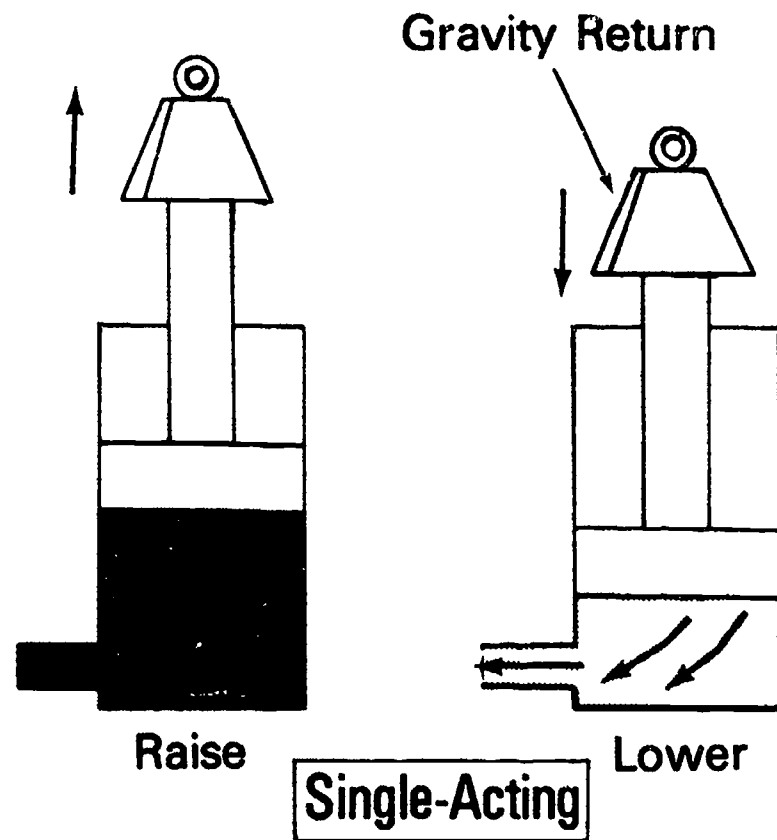
### XII. Symbol for a cylinder



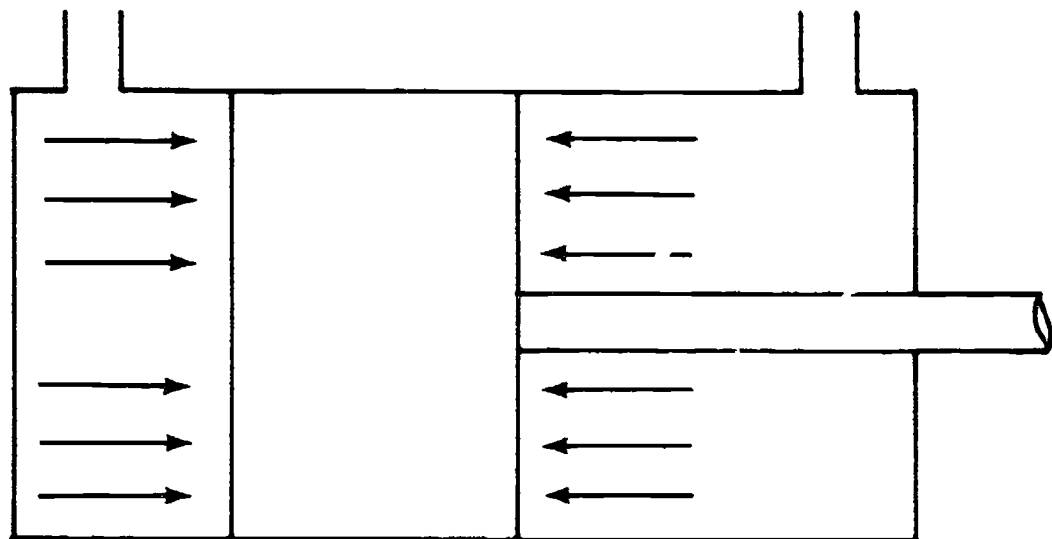
# Operation of a Hydraulic Cylinder



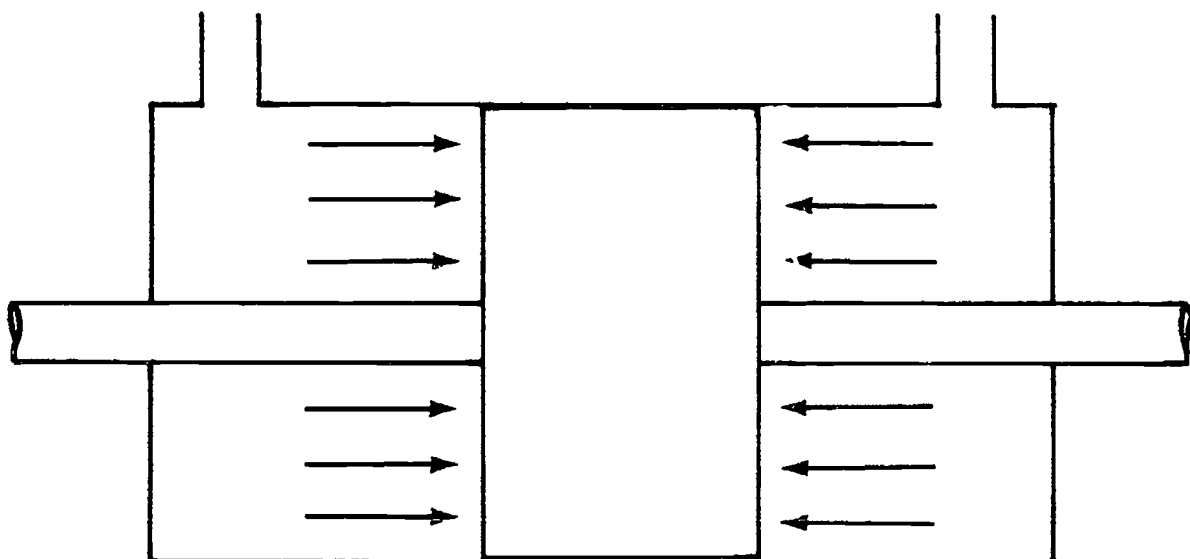
# Operation of Single and Double Acting Cylinders



# Types of Double-Acting Hydraulic Cylinders

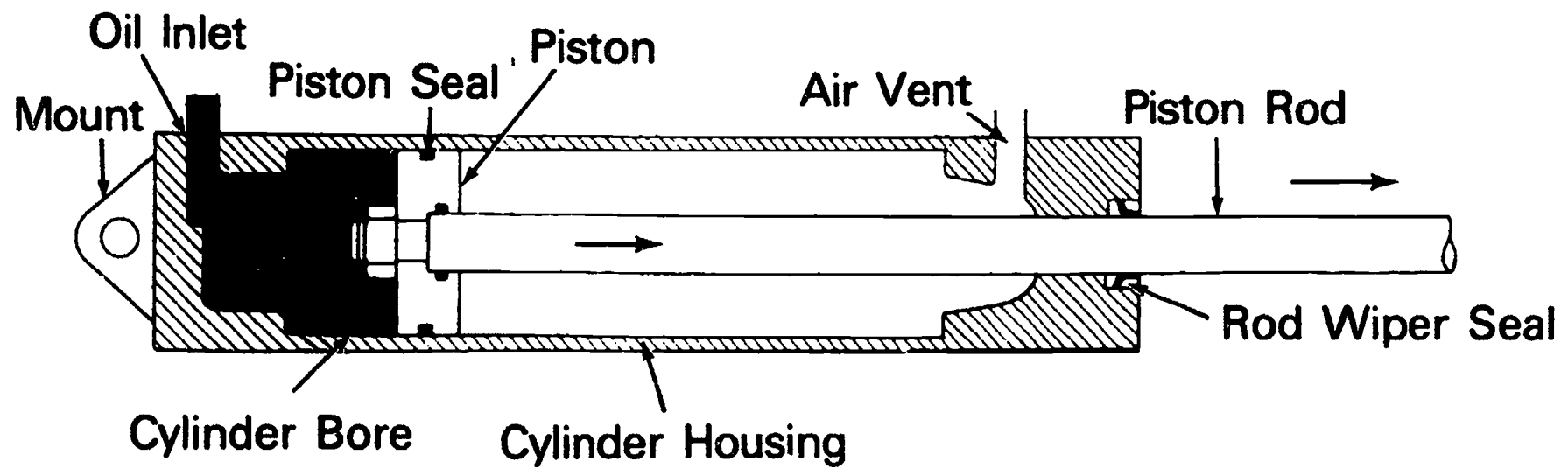


Unbalanced (Differential Type)



Balanced (Equal force both ways)

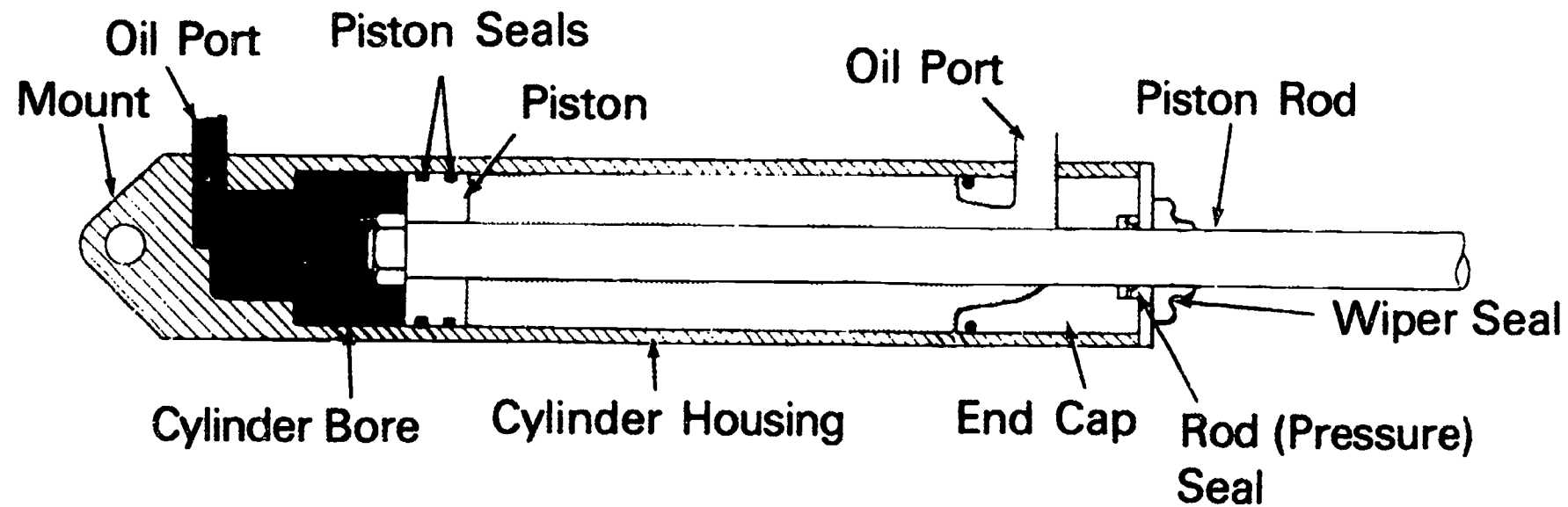
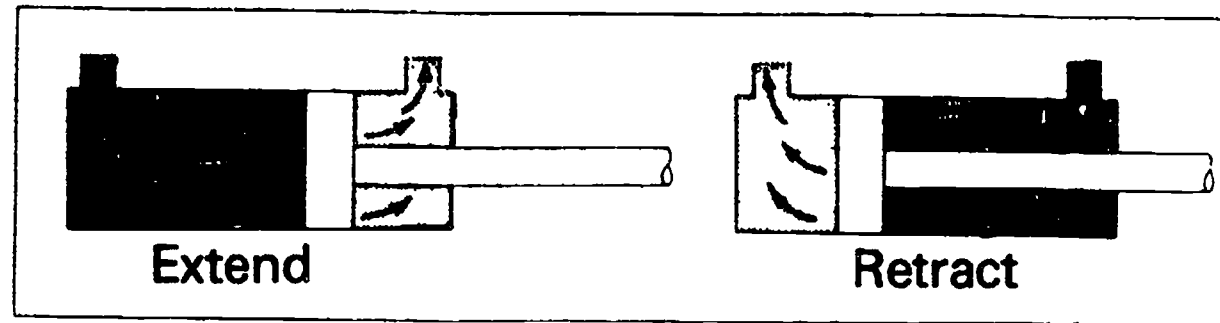
# Single-Acting Cylinder



230

231

# Double-Acting Cylinder



## CYLINDERS UNIT IX

### JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A HYDRAULIC CYLINDER

**A. Tools and materials**

1. Wrenches of appropriate sizes
2. Cylinder
3. Replacement piston seal
4. Replacement rod seal
5. Replacement wiper seal

**B. Routine #1 — Disassemble the cylinder**

1. Use scribe to place match marks on end caps
2. Use appropriate wrenches to remove end cap
3. Remove rod assembly from cylinder barrel

☐ Have your instructor check your work

**C. Routine #2 — Inspect the cylinder**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine cylinder barrel for scoring or abnormal wear		
2. Examine piston seal for nicking or uneven wear		
3. If the cylinder uses a piston seal, inspect for nicking or uneven wear		
4. If the cylinder uses a wiper seal, inspect for damage or nicking		
5. Examine the air vent or single-acting cylinders to insure the opening is not obstructed		

☐ Have your instructor check your work

**JOB SHEET #1****D. Routine #3 — Reassemble the cylinder**

1. Remove old piston seal
2. Carefully install a new piston seal onto the piston
3. Carefully insert rod assembly into the cylinder barrel
4. Install a new rod seal (if used)
5. Make sure orientation is correct (lip is out) and that seal is square to the rod
6. Install end cap
7. Align match marks
8. Tighten the bolts evenly on cylinders using the rods
- ☐ Have your instructor check your work
9. Clean up area and return tools and materials to proper storage



## **CYLINDERS UNIT IX**

### **JOB SHEET #2 — TEST A CYLINDER FOR INTERNAL AND EXTERNAL LEAKAGE**

**A. Tools and materials**

1. Wrenches as required
2. Cylinder test fixture capable of holding a pressurized cylinder
3. Double-acting cylinder
4. Safety glasses

**B. Routine #1 — Test for external leakage**

1. With cylinder installed on machine or test fixture, apply pressure and visually inspect for leakage around the rod at the end cap
2. Repeat for several different positions

☐ Have your instructor check your work

**C. Routine #2 — Test a double-acting cylinder for internal leakage**

1. Install cylinder on test fixture, leaving the line to one side of the cylinder unconnected

(NOTE: Only one side of the cylinder will be pressurized at a time.)

2. Bleed air from the side of the cylinder which will be pressurized
3. Apply pressure
4. Observe open outlet for any leakage flow
5. Repeat for several cylinder extensions
6. Remove pressure
7. Disconnect line to cylinder and reconnect to other side
8. Repeat steps 2 to 6 for other side of cylinder

☐ Have your instructor check your work

9. Clean up area and return tools and materials to proper storage

# **CYLINDERS UNIT IX**

NAME \_\_\_\_\_

## **TEST**

1. Match the terms on the right with the correct definitions.

- |         |   |                  |
|---------|---|------------------|
| _____a. | Area of the piston rod  | 1. Piston area   |
| _____b. | Area of the cylinder piston   | 2. Back pressure |
| _____c. | Effective area on the rod side of the cylinder; equal to the piston area minus the rod area | 3. Rod area      |
| _____d. | An actuator which converts hydraulic power into linear mechanical force and motion          | 4. Rod side area |
| _____e. | Pressure in the return lines caused by flow in these lines                                  | 5. Cylinder      |

2. Discuss the operation of a hydraulic cylinder.

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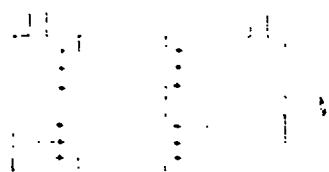


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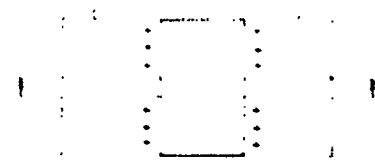
3. Distinguish between the operation of single-acting and double-acting cylinders by placing an "X" next to the descriptions of single acting cylinders.

- |         |   |
|---------|---|
| _____a. | Oil flows into only one side of the cylinder                              |
| _____b. | The cylinder is retracted by oil flow into the other side of the cylinder |
| _____c. | The cylinder is retracted by gravity or a spring                          |
| _____d. | Oil flows into one side to extend the cylinder                            |

4. Identify types of double-acting cylinders.



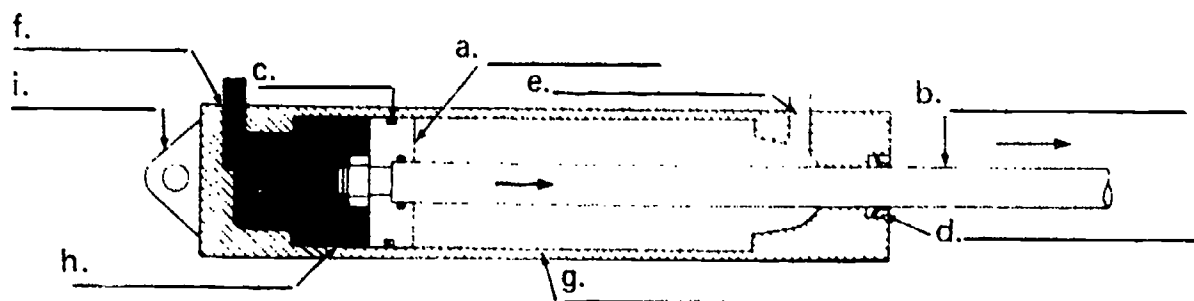
a. \_\_\_\_\_



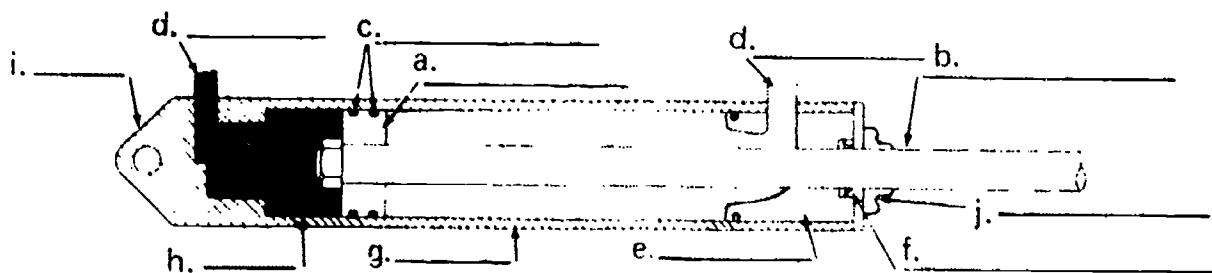
b. \_\_\_\_\_

## TEST

5. Identify the parts of a single-acting cylinder.



6. Identify the parts of a double-acting cylinder.



7. List five sources of common failures of hydraulic cylinders.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

# TEST

8. Calculate the force output in the following problems.
- a. Using the formula for single-acting force,  $F = PA$ , calculate the force if  $P = 2000$  PSI and  $D = 4.00$  inches
- b. Using the formula for double-acting force,  $\text{Piston area} \times \text{Piston pressure}$ , and  $\text{Rod side area} \times \text{Rod side pressure}$ , calculate the force when
- Piston pressure = 2000 PSI  
Rod diameter = 3.0 inches  
Piston diameter = 4.00 inches  
Rod-side pressure = 500 PSI
9. Calculate the speed of hydraulic cylinders in the following problems.
- a. Using the formula for single-acting rod speed,  $\frac{\text{flow rate} \times 19.25}{\text{Piston area}}$ , calculate rod speed when
- Flow rate into cylinder =  $Q = 10$  GPM  
Piston diameter =  $P = 4$  inches  
Constant = 19.25
- b. Using the formula for double-acting rod speed,  $\frac{\text{flow rate} \times 19.25}{\text{Area}}$ , calculate the retracting and extending speed when
- Piston diameter = 3 inches  
Rod diameter = 2 inches  
Piston area = 7.07 sq. in.  
Rod area = 3.14 sq. in.  
Rod side area = 3.93 sq. in.  
Flow rate = 10 GPM
- 1) Retracting speed \_\_\_\_\_
- 2) Extending speed \_\_\_\_\_

## TEST

10. Using the formula for power output of a cylinder,  $\frac{V \times F}{33,000}$ , calculate the power output of a cylinder, when

V = Rod velocity = 20 ft/sec

F = Rod force = 10,000 pounds force

Constant = 33,000

11. Using the formula for the flow rate required to move a cylinder a given distance in a given time,  $Q = \frac{A \times L}{T \times 231}$ , calculate the flow rate required to move a 2 inch diameter cylinder 10 inches in one minute.

12. Draw the symbol for a cylinder.

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)


13. Demonstrate the ability to:
- Disassemble, inspect, and reassemble a hydraulic cylinder.
  - Test a cylinder for internal and external leakage.

## CYLINDERS UNIT IX

### ANSWERS TO TEST

1.   a.     3                   c.     4                   e.     2  
      b.     1                   d.     5
  
2.   Discussion should include:
  - a.     Hydraulic oil flows into a chamber of the cylinder, causing the cylinder rod to move
  - b.     Pressure of the fluid acting on the surface of a piston creates a force on the rod
  
3.   a, c
  
4.   a.     Unbalanced  
      b.     Balanced
  
5.   a.     Piston  
      b.     Piston rod  
      c.     Piston seal  
      d.     Rod wiper seal  
      e.     Air vent  
      f.     Oil inlet  
      g.     Cylinder housing  
      h.     Cylinder bore  
      i.     Mount
  
6.   a.     Piston  
      b.     Piston rod  
      c.     Piston seals  
      d.     Oil ports  
      e.     End cap  
      f.     Rod seal  
      g.     Cylinder housing  
      h.     Cylinder bore  
      i.     Mount  
      j.     Wiper seal
  
7.   Any five of the following:
  - a.     Bent rod
  - b.     Scored cylinder barrel
  - c.     Nicked or damaged rod
  - d.     Leaking piston seal
  - e.     Leaking rod seal
  - f.     Defective wiper seal

## ANSWERS TO TEST

8. a. 25.120 lbs.  
b. 22.157.5 lbs.
9. a. 15.33 ft/min  
b. 1) 48.98 ft/min  
2) 15.33
10. 6.06 HP
11. .136 GPM
12. 
13. Performance skills evaluated to the satisfaction of the instructor

## **MOTORS**

### **UNIT X**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to calculate hydraulic motor load torque, displacement, speed, inlet pressure, power, and efficiency. The student should also be able to select true statements concerning the operation of a gear motor, a vane motor, an in-line axial piston motor. The student should also be able to disassemble, inspect, and reassemble a gear motor. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheet and by scoring 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to motors with their correct definitions.
2. Name three kinds of hydraulic motors.
3. Given a formula, calculate hydraulic motor load torque.
4. Given a formula, calculate the displacement of a hydraulic motor.
5. Given a formula, calculate the speed of a hydraulic motor.
6. Given a formula, calculate hydraulic motor inlet pressure.
7. Given a formula, calculate hydraulic motor input and output power.
8. Given a formula, calculate motor overall efficiency.
9. Select true statements concerning the operation of a gear motor.
10. Select true statements concerning the operation of an unbalanced vane motor.
11. Name three types of piston motors.
12. Select true statements concerning the operation of an in-line axial piston motor.
13. Demonstrate the ability to disassemble, inspect, and reassemble a gear motor. (Job Sheet #1)



## MOTORS UNIT X

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheet.
- G. Show students examples of vane, gear, and piston motors.
- H. Give test.

### CONTENTS OF THIS UNIT

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Motor Load Torque
  - 2. TM 2 — Operation of a Gear and Vane Motor
  - 3. TM 3 — Operation of an In-Line Axial Piston Motor
- D. Job Sheet #1 — Disassemble, Inspect, and Reassemble a Gear Motor
- E. Test
- F. Answers to test

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1967.
- B. *Fluid Power 1*. Cleveland, OH 44112: Parker-Hannifin Corporation, 1975.

# MOTORS

## UNIT X

### INFORMATION SHEET

#### I. Terms and definitions

- A. Hydraulic motor — A device for converting fluid energy into mechanical force and motion
- B. Torque — A measure of rotational (twisting) load or effort; calculated as force times distance
- C. Displacement — The volume of fluid which is transported from the motor inlet to the outlet during one revolution of the motor
- D. Efficiency — The output power divided by the input power
- E. Foot-pound — A unit of torque equal to 12 inch-pounds  
(NOTE: Foot-pounds are abbreviated ft-lbs.)
- F. Back pressure — Pressure at the outlet of a motor caused by pressure drop in the return lines

#### II. Kinds of hydraulic motors

- A. Gear
- B. Vane
- C. Piston

(NOTE: These are positive displacement motors. Nonpositive displacement motors do exist but are not commonly used in hydraulic systems.)

#### III. Formula for calculation of hydraulic motor load torque (Transparency 1) — Torque = Distance $\times$ Force

Where Torque is expressed in ft-pounds or inch-pounds

Force = Load force expressed in pounds

Distance = Distance from center of shaft to line of action of applied force, measured perpendicular to line of action and expressed in units of inches or feet

Example: If a 100 pound force is applied to the shaft of a hydraulic motor one foot from the center of the shaft, then the output torque is 100 ft-pounds

Torque = Distance  $\times$  Force

Torque = (1 ft) (100 pounds) = 100 ft-pounds

## INFORMATION SHEET

### IV. Formula for calculating the displacement of a hydraulic motor — $d = \frac{231 Q}{n}$

Where  $d$  = Displacement in units of cubic inches per revolution (in.<sup>3</sup>/rev)  
 $Q$  = Motor inlet flowrate in units of gallons per minute (GPM)  
 $n$  = Shaft speed in units of revolutions per minute (RPM)

Example: The displacement of a motor which has a shaft speed of 1800 RPM when the inlet flowrate is 20 GPM is 2.56 in<sup>3</sup>/rev.

$$d = \frac{231 \times 20 \text{ GPM}}{1800 \text{ RPM}} = 2.56 \text{ in}^3/\text{rev}.$$

### V. Formula for calculating the speed of a hydraulic motor — $n = \frac{Q \times 231}{d}$

Where  $n$  = Shaft speed in units of revolutions per minute (RPM)  
 $Q$  = Motor inlet flowrate in units of gallons per minute (GPM)  
 $d$  = Displacement in units of cubic inch per revolution (in<sup>3</sup>/rev.)

Example: the speed of a 2.56 in<sup>3</sup>/rev motor with an inlet flowrate of 25 GPM is 2255 RPM

$$n = \frac{(25 \text{ GPM}) \times 231}{2.56 \text{ in}^3/\text{rev}} = 2255 \text{ RPM}$$

### VI. Formula for calculating hydraulic motor inlet pressure —

$$P = \frac{\text{Torque} \times 2\pi}{d} \quad (\pi = 3.14)$$

Where  $P$  = Inlet pressure in units of pounds per square inch (PSI)  
Torque = Shaft torque in units of inch-pounds (in-lbs.)

$d$  = Displacement in cubic inches per revolution (in<sup>3</sup>/rev)

Example: A hydraulic motor has a displacement of 2.56 cubic inches per revolution. The load torque is 700 in-lbs. The inlet pressure is 1717 PSI.

$$P = \frac{(700 \text{ in-lbs.}) \times 6.28}{2.56} = 1717$$

## INFORMATION SHEET

### VII. Formula for calculating hydraulic motor power

A. Input power —  $\text{Power} = \frac{P \times Q}{1714}$

Where Power = Input in units of horsepower (HP)

P = Inlet pressure in units of PSI

Q = Inlet flowrate in units of GPM

Example: The input power of a hydraulic motor operating at 20 GPM inlet flow and 3000 PSI inlet pressure is 35 HP

$$\text{Power} = \frac{3000 \text{ PSI} \times 20 \text{ GPM}}{1714} = 35 \text{ HP}$$

B. Output power —  $\text{Power} = \frac{n \times \text{Torque}}{5252}$

Where Power = Output power in units of horsepower (HP)

n = Shaft speed in units of revolutions per minute (RPM)

Torque = Output torque in units of foot-pounds (ft-lbs.)

Example: The output power of a hydraulic motor operated at 2400 RPM with an output load of 70 ft-lbs. is 32 HP

$$\text{Power} = \frac{(2400 \text{ RPM}) (70 \text{ ft-lbs.})}{5252} = 32 \text{ HP}$$

### VIII. Formula for the calculation of motor overall efficiency —

$$\text{Eff} = \frac{\text{Output power}}{\text{Input power}}$$

Example: A motor is operated at the output power of 27 HP. The input power required is 32 HP. The efficiency is 0.844.

$$\text{Eff} = 27/32 = 0.844; \text{ Therefore the motor is 84.4\% efficient.}$$

### IX. Operation of a gear motor (Transparency 2)

- A. Pressurized hydraulic fluid is supplied to the inlet of the motor
- B. The pressure creates a force on the face of each gear tooth
- C. The pressure force on the gear teeth is balanced; a force on one face which would tend to cause rotation in the clockwise direction is balanced by a force on an adjacent face which would tend to cause rotation in the opposite direction

## INFORMATION SHEET

- D. This balancing of forces exist at all gear teeth except where the teeth just begin to unmesh
- E. At this location, the forces are not balanced which tends to cause the motor to rotate
- F. As the motor rotates, small volumes of fluid are trapped between the gear teeth and are carried to the outlet
- G. The fluid at the outlet is expelled at a lower pressure

(NOTE: The operation of an external gear motor has been discussed. Other types of gear motors do exist.)

### X. The operation of an unbalanced vane motor (Transparency 2)

- A. A vane motor consists of a ring, vanes, rotor, shaft, and a port plate with kidney shaped inlet and outlet ports
- B. The rotor is installed off-centered in the ring
- C. The vanes are installed into the rotor and are free to move radially
- D. The vanes are spring-loaded to force the vanes to contact the surface of the ring

(NOTE: Hydraulic pressure may be used to force the rotors against the ring.)

- E. Pressurized hydraulic fluid is supplied to the inlet of the motor
- F. Because the rotor is installed off center, an imbalance on the vanes is created which tends to cause the rotor and motor shaft to turn
- G. As the rotor turns a small volume of fluid is trapped and carried to the outlet and expelled at a lower pressure

(NOTE: Some vane motors are designed to balance the load on the shaft bearing by having two inlet and two outlet ports. The inlet ports are positioned directly opposite each other. This design is called a balanced vane motor.)

### XI. Types of piston motors

- A. Radial
- B. In-line axial
- C. Bent axis axial

24

## INFORMATION SHEET

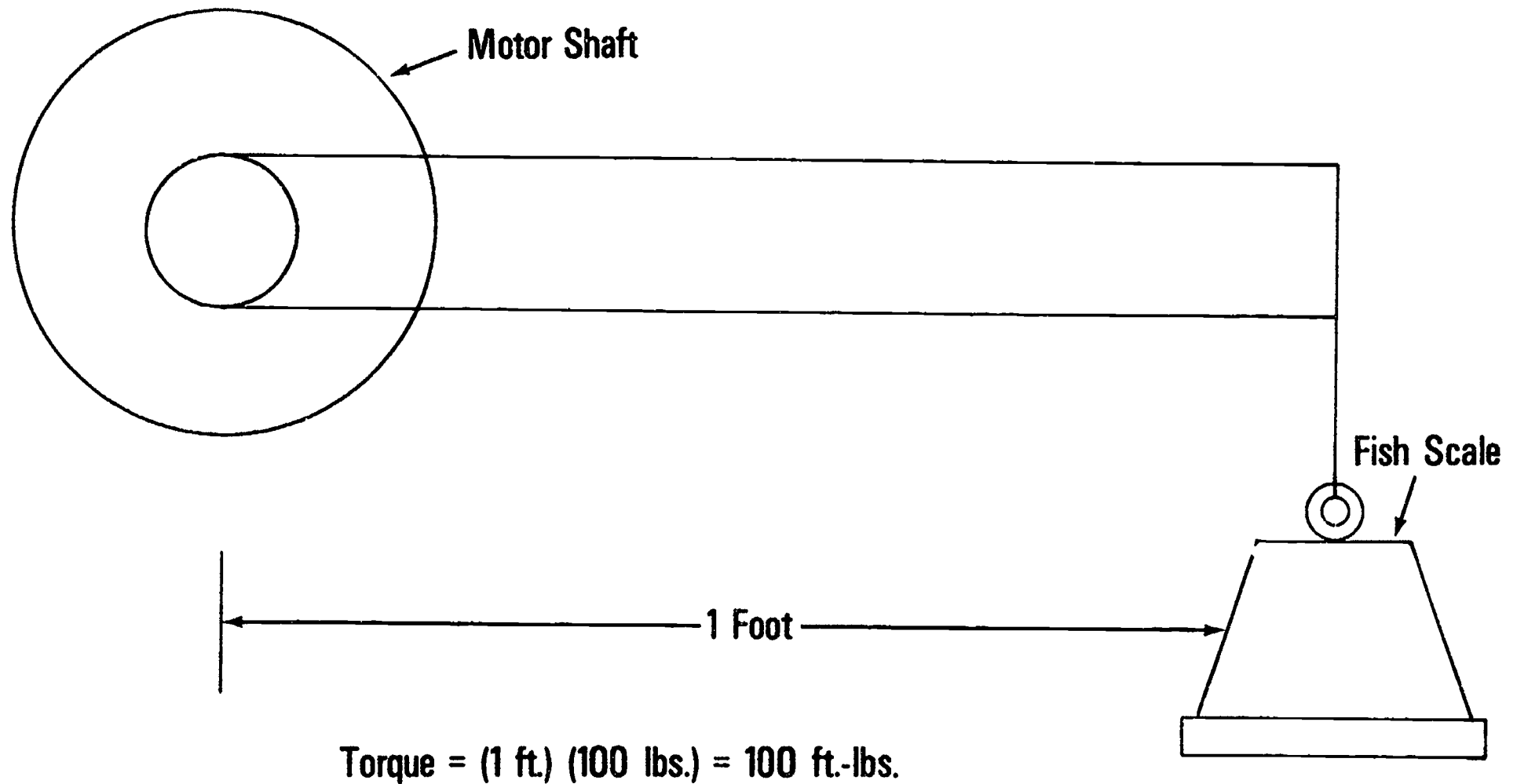
### XII. Operation of an in-line axial piston motor (Transparency 3)

- A. The motor consists of a swash plate, pistons with shoes, a cylinder barrel, shaft, and port plate
- B. The pistons are installed in the cylinder barrel and are connected with the swash plate
- C. The swash plate is positioned at an angle thus causing the pistons to extend into the cylinder block a varying amount
- D. Pressurized hydraulic fluid is supplied to the inlet of the motor, which causes a force to be applied to the top of a piston
- E. This, in turn, causes the piston and shoe to slide on the swash plate from the high side to the low side causing the cylinder barrel and shaft to rotate (Transparency 5)

(NOTE: The swash plate does not rotate with the pistons, cylinder barrel and shaft.)

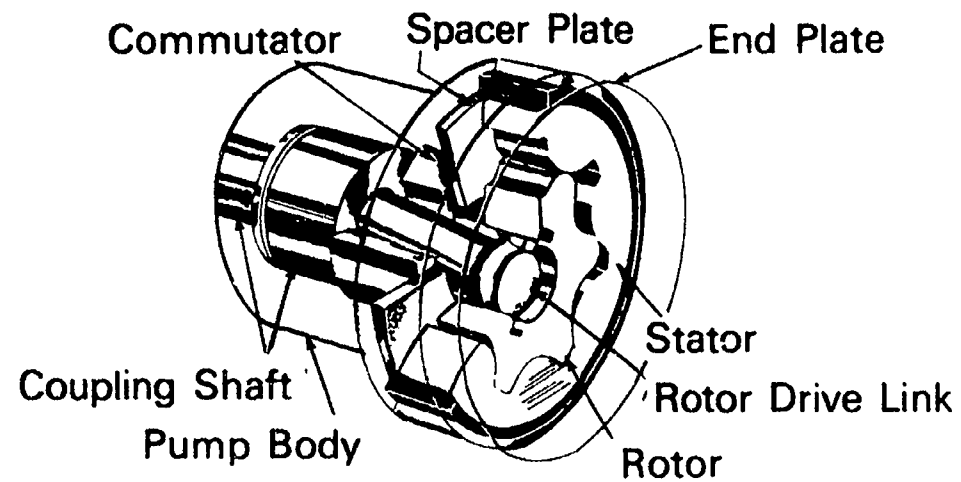
- F. As each piston is forced to move, it rotates from the inlet to the outlet
- G. In doing this it carries a small amount of fluid from the inlet to outlet
- H. This fluid is expelled from the outlet at a lower pressure

# Motor Load Torque

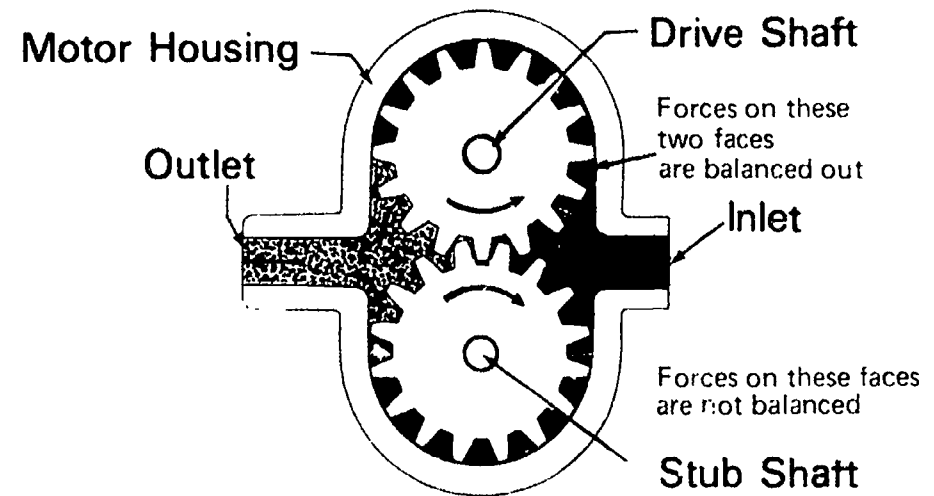


# Operation of a Gear and Vane Motor

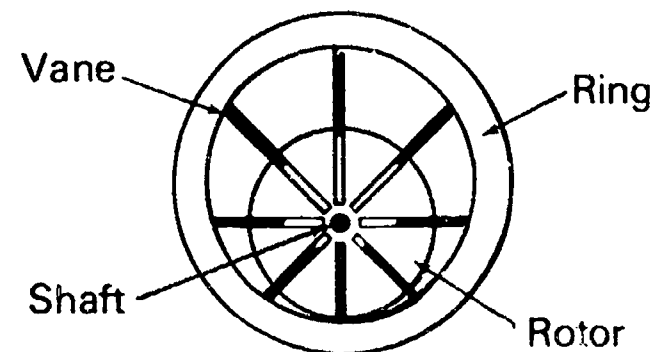
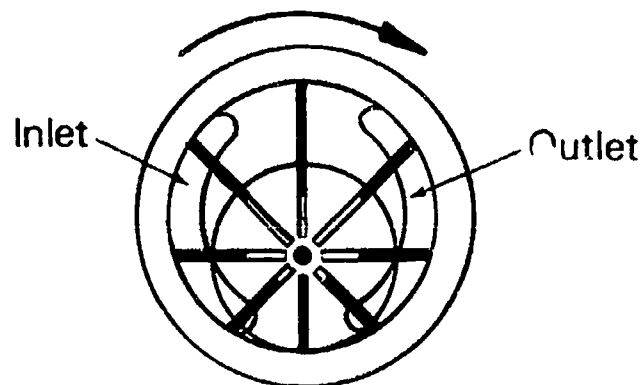
## Internal Gear Motor



## External Gear Pump in Operation

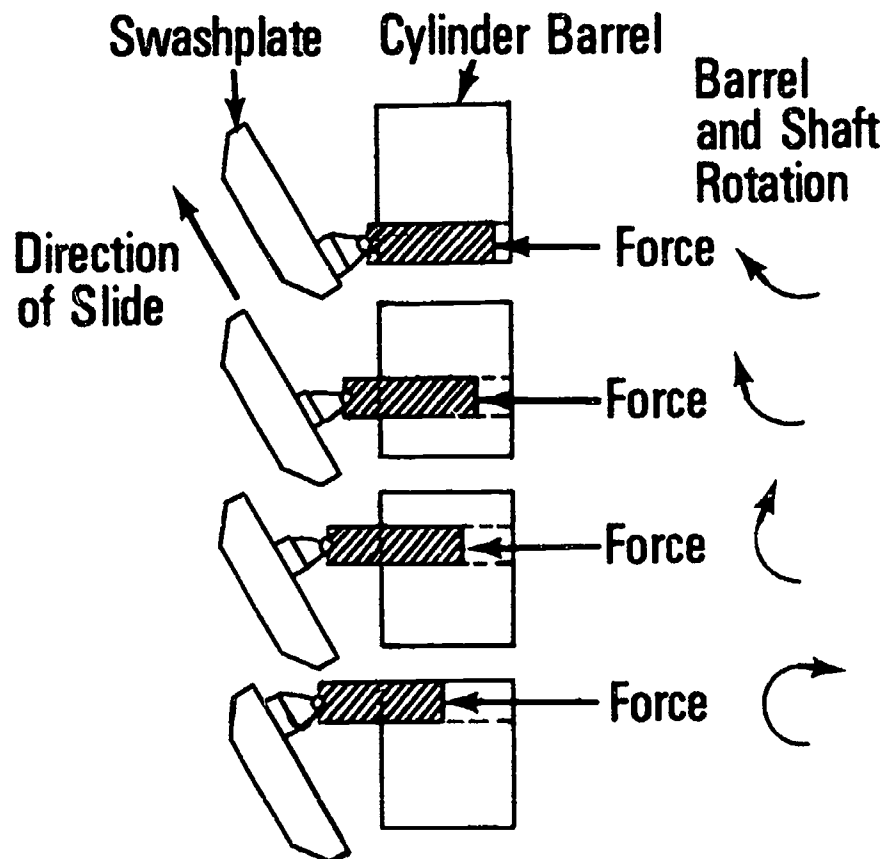
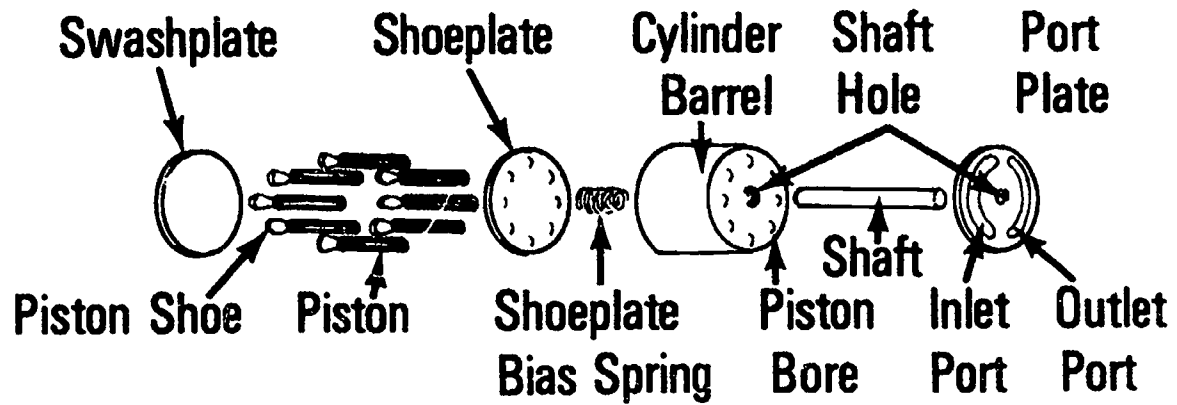


## Vane Motor





# Operation of an In-Line Axial Piston Motor



## MOTORS UNIT X

### JOB SHEET #1 — DISASSEMBLE, INSPECT, AND REASSEMBLE A GEAR MOTOR

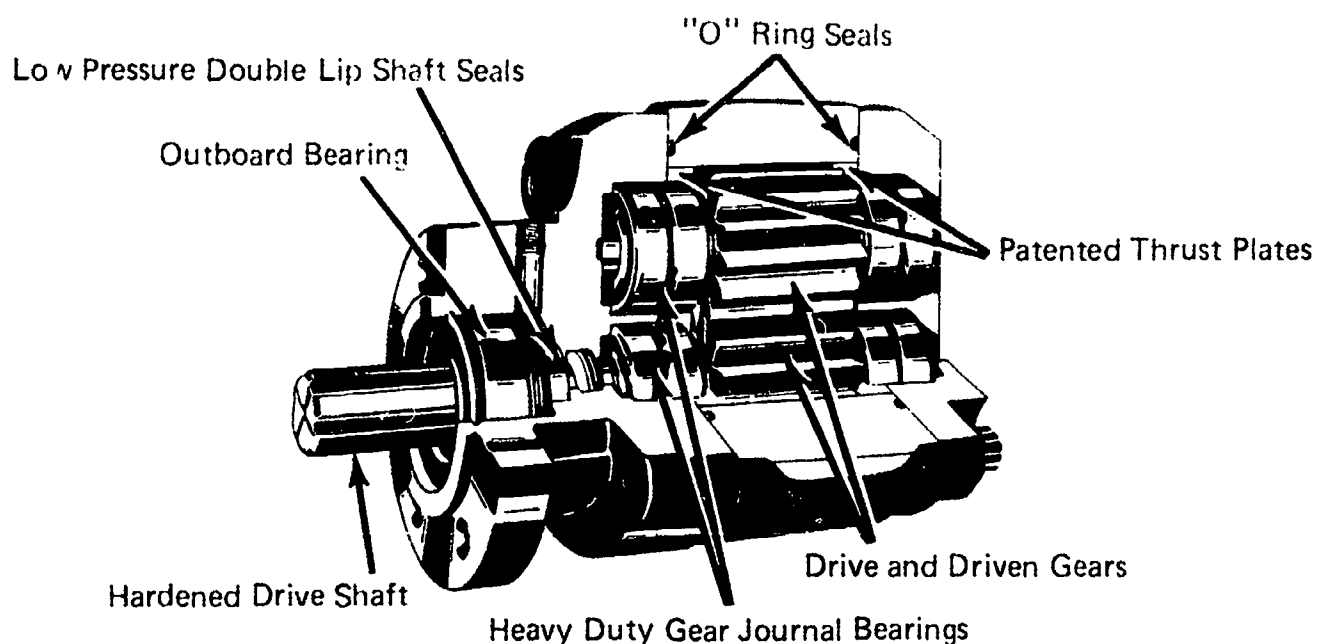
A. Tools and materials

1. Gear motor
2. Service manual for motor (if available)
3. Hand tool set
4. Solvent
5. Lint free shop towels
6. Safety glasses

B. Routine #1 — Disassemble the gear motor

(NOTE: Figure 1 shows a cut-away drawing of a typical gear motor with an outboard bearing on the motor shaft. Figure 2 is an exploded view of this motor.)

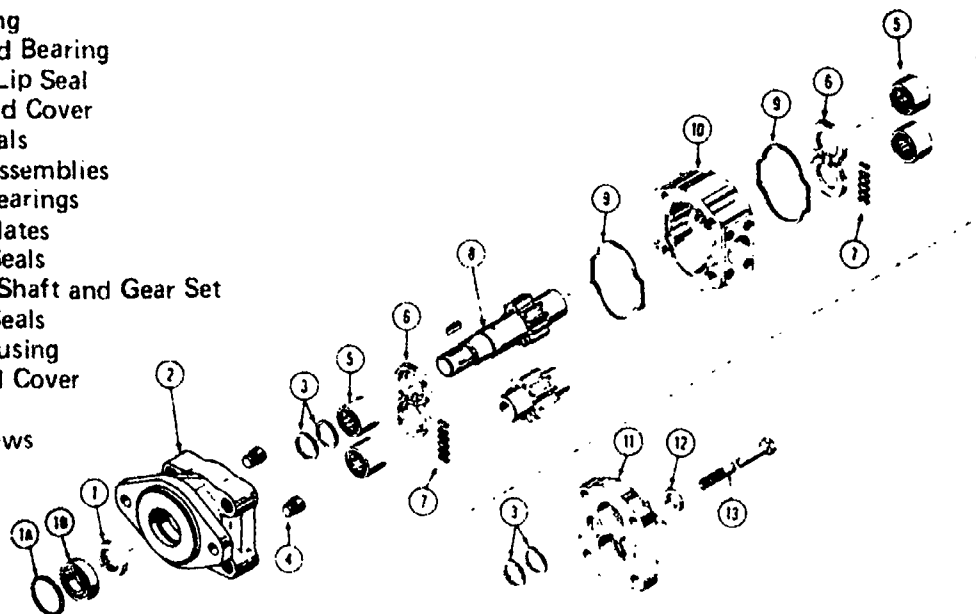
FIGURE 1



## JOB SHEET #1

**FIGURE 2**

- 1A Snap Ring
- 1B Outboard Bearing
- 1 Double Lip Seal
- 2 Shaft End Cover
- 3 Shaft Seals
- 4 Check Assemblies
- 5 Roller Bearings
- 6 Thrust Plates
- 7 Pocket Seals
- 8 Integral Shaft and Gear Set
- 9 Gasket Seals
- 10 Gear Housing
- 11 Port End Cover
- 12 Washers
- 13 Cap Screws



**FIGURE 2**

1. Thoroughly clean the external surfaces of the motor with solvent and dry the motor with shop towels
  2. Place the motor on a clean surface for disassembly
  3. Remove the clip ring retainer on the outboard shaft bearing (if used)
  4. Remove the bearing
  5. Remove the four cap screws which hold the motor housing together
  6. Slowly remove the port (rear) end cover from the motor
  7. Remove the two port side roller bearings from the assembly
  8. Remove the rear thrust plate, noting orientation of the plate
  9. Remove the gear housing from the motor
  10. Carefully remove the two gears from the motor
  11. Remove the shaft side thrust plate, noting orientation of plate
  12. Remove the two shaft side roller bearings
  13. Remove shaft seal
- ☐ Have your instructor check your work

**JOB SHEET #1****C. Routine #2 — Inspect the gear motor**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine the two thrust plates for excessive wear or condition scoring		
2. Examine the gears for excessive wear and broken teeth		
3. Examine the roller bearings for excessive wear and fractured bearings		
4. Examine the shaft seal for scoring		
5. Examine the gear housing seals (usually O-rings) for nicks or breaks		
6. Replace any part found to be defective		

☐ Have your instructor check your work

**D. Routine #3 — Reassemble the gear motor**

(NOTE: Pre-lube parts during assembly.)

1. Carefully install the shaft seal
2. Install the two shaft-side roller bearings
3. Install the shaft side thrust plate
4. Install the two gears into the shaft end cover
5. Insure that the two seals on the gear housing are properly installed and then lower the gear housing around the two gears and align with the shaft end cover
6. Install the port side thrust plate
7. Install the port side roller bearings
8. Install the port side end cover onto the assembly and carefully align
9. Install the four cap screws

**JOB SHEET #1**

10. Uniformly torque the screws by alternately applying torque to screws on opposite sides of the motor
11. Reinstall the shaft outboard bearing and clip ring
12. Fill motor with fluid as specified by the manufacturer before operation
- ☐ Have your instructor check your work
13. Clean up area and return tools and materials to proper storage

## MOTORS UNIT X

NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with the correct definitions.

- |         |  |                    |
|---------|--|--------------------|
| _____a. | A measure of rotational load or effort; calculated as force times distance                                     | 1. Back pressure   |
| _____b. | The output power divided by the input power  | 2. Hydraulic motor |
| _____c. | The volume of fluid which is transported from the motor inlet to the outlet during one revolution of the motor | 3. Displacement    |
| _____d. | A device for converting fluid energy into mechanical force and motion  | 4. Torque          |
| _____e. | A unit of torque equal to 12 inch-pounds   | 5. Efficiency      |
| _____f. | Pressure at the outlet of a motor caused by pressure drop in the return lines                                  | 6. Foot-pound      |

2. Name three kinds of hydraulic motors.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

3. Using the formula for torque, calculate hydraulic motor load torque if a 150 pound force is applied to the shaft of a hydraulic motor two feet from the center of the shaft.

Torque = Distance  $\times$  Force

## TEST

4. Using the formula for displacement, calculate the displacement of a motor which has a shaft speed of 1750 RPM when the inlet flowrate is 22 GPM.

$$d = \frac{231 Q}{n}$$

5. Using the formula for speed, calculate the speed of a 2.56 in<sup>3</sup>/rev. hydraulic motor with an inlet flowrate of 24 GPM.

$$n = \frac{Q \times 231}{d}$$

6. Using the formula for inlet pressure, calculate inlet pressure of a hydraulic motor which has a displacement of 2.56 cubic inches per revolution and a load torque of 750 in-lbs.

$$P = \frac{\text{Torque} \times 2\pi}{d}$$

7. a. Using the formula for input power, calculate the input power of a motor operating at 21 GPM inlet flow and 2500 PSI inlet pressure.

$$\text{Power} = \frac{P \times Q}{1714}$$

- b. Using the formula for output power, calculate the output power of a motor which is operating at 2000 RPM with an output load of 50 ft-lbs.

$$\text{Power} = \frac{n \times \text{Torque}}{5252}$$

## TEST

8. Using the formula  $\text{Eff} = \frac{\text{Output power}}{\text{Input power}}$ , calculate the motor overall efficiency if the output power is 25 HP and the input power is 30 HP.
9. Select true statements concerning the operation of a gear motor by placing an "X" in the appropriate blanks.
- \_\_\_\_\_a. Pressurized hydraulic fluid is supplied to the inlet of the motor
  - \_\_\_\_\_b. The pressure creates a force on the face of each gear tooth
  - \_\_\_\_\_c. The pressure force on the gear teeth is balanced; a force on one face which would tend to cause rotation in the clockwise direction is balanced by a force on an adjacent face which would tend to cause rotation in the opposite direction
  - \_\_\_\_\_d. This balancing of forces exist at all gear teeth except where the teeth just begin to unmesh
  - \_\_\_\_\_e. At this location, the forces are not balanced which tends to cause the motor to rotate
  - \_\_\_\_\_f. As the motor rotates, small volumes of fluid are trapped between the gear teeth and are carried to the outlet
  - \_\_\_\_\_g. The fluid at the outlet is expelled at a much higher pressure
10. Select true statements concerning the operation of an unbalanced vane motor by placing an "X" in the appropriate blanks.
- \_\_\_\_\_a. A vane motor consists of a ring, vanes, rotor, shaft, and a port plate with kidney shaped inlet and outlet ports
  - \_\_\_\_\_b. The rotor is installed in the center of the ring
  - \_\_\_\_\_c. The vanes are installed into the port plate and cannot move
  - \_\_\_\_\_d. The vanes are spring-loaded to force the vanes to contact the surface of the ring
  - \_\_\_\_\_e. Pressurized hydraulic fluid is supplied to the inlet of the motor
  - \_\_\_\_\_f. At this point the vanes are balanced and the rotor turns
  - \_\_\_\_\_g. As the rotor turns a small volume of fluid is trapped and carried to the outlet and expelled at a lower pressure



**TEST**

11. Name three types of piston motors.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

12. Select true statements concerning the operation of an in-line axial piston motor by placing an "X" in the appropriate blanks.

- \_\_\_\_\_a. The motor consists of a swash plate, pistons with shoes, a cylinder barrel, shaft, and port plate
- \_\_\_\_\_b. The swash plate is positioned at an angle thus causing the pistons to extend into the cylinder block a varying amount
- \_\_\_\_\_c. Pressurized hydraulic fluid is supplied to the inlet of the motor, which causes a force to be applied to the shaft
- \_\_\_\_\_d. This, in turn, causes the piston and shoe to slide on the swash plate from the high side to the low side, causing the cylinder barrel and shaft to rotate
- \_\_\_\_\_e. As each piston is forced to move, it rotates from the outlet to the inlet
- \_\_\_\_\_f. In doing this it carries a small amount of fluid from the inlet to the outlet
- \_\_\_\_\_g. This fluid is expelled from the outlet at a lower pressure

(NOTE: If the following activity has not been accomplished prior to the test, ask your instructor when it should be completed.)

13. Demonstrate the ability to disassemble, inspect, and reassemble a gear motor.

## MOTORS UNIT X

### ANSWERS TO TEST

1.   a.     4                   c.     3                   e.     6  
      b.     5                   d.     2                   f.     1
2.   a.     Gear  
      b.     Vane  
      c.     Piston
3.   300 ft-lbs.
4.   2.9 in/rev.
5.   2165 RPM
6.   1840 PSI
7.   a.     30.6 HP  
      b.     19 HP
8.   83%
9.   a, b, c, d, e, f
10.  a, d, e, g
11.  a.     Radial  
      b.     In-line axial  
      c.     Bent axis axial
12.  a, b, d, f, g
13.  Performance skill evaluated to the satisfaction of the instructor

## **ACCESSORIES**

### **UNIT XI**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to list safety precautions for working with accumulators and explain reasons for using a cooler and a heater. The student should also be able to inspect, clean, and test a cooler and a heater. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Define terms associated with accessories.
2. Select functions of an accumulator.
3. Identify types of accumulators.
4. Identify types of gas-loaded accumulators.
5. List safety precautions for working with accumulators.
6. Explain reasons for using a cooler.
7. Describe types of coolers.
8. Match components of an air-cooled cooler with their functions.
9. List common failures of coolers.
10. Explain reasons for using a heater.
11. Describe two types of heaters.
12. List two common failures of heaters.
13. Demonstrate the ability to:
  - a. Inspect, clean, and test an air-cooled cooler. (Job Sheet #1)
  - b. Inspect, clean, and test a heater. (Job Sheet #2)

## ACCESSORIES UNIT XI

### SUGGESTED ACTIVITIES

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheets.
- G. Demonstrate how to recharge an accumulator according to manufacturer's specifications.
- H. Give test.

### CONTENTS OF THIS UNIT

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Types of Accumulators
  - 2. TM 2 — Types of Gas-Loaded Accumulators
  - 3. TM 3 — Air-Cooled Cooler
  - 4. TM 4 — Water-Cooled Cooler
- D. Job sheets
  - 1. Job Sheet #1 — Inspect, Clean, and Test an Air-Cooled Cooler
  - 2. Job Sheet #2 — Inspect, Clean, and Test a Heater
- E. Test
- F. Answers to test

### REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company. 1967.
- B. *Service Manual SM2039, John Deere 4000 Tractor*. Waterloo, IA: Deere and Company. 1967.
- C. *Ford Tractor Repair Manual*. Troy, MI: Tractor Operations. Ford Motor Company. 1983.

## **ACCESSORIES UNIT XI**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Accumulator — A device for storing hydraulic energy
- B. Cooler — A device for removing heat from hydraulic fluids
- C. Heater — A device for adding heat to hydraulic fluids
- D. Thermostat — An automatic device for regulating temperature

#### **II. Functions of an accumulator**

- A. Stores energy
- B. Absorbs shock
- C. Allows the system to build pressure gradually
- D. Maintains pressure

#### **III. Types of accumulators (Transparency 1)**

- A. Gas-loaded (gas-charged)
- B. Weight-loaded
- C. Spring-loaded

#### **IV. Types of gas-loaded accumulators (Transparency 2)**

- A. Piston type
- B. Bladder type
- C. Diaphragm type

#### **V. Safety precautions for working with accumulators**

(NOTE: Accumulators are used to store energy and therefore can pose severe safety hazards.)

- A. Always discharge stored hydraulic fluid from the accumulator prior to removing it from the system

(NOTE: Valves, brake pedals, etc., should be operated to insure all stored hydraulic energy has been expelled. Failure to do this could result in severe injury from high pressure fluid escaping.)

## INFORMATION SHEET

- B. Never charge an accumulator to a pressure more than that recommended by the manufacturer
- C. *Never* fill an accumulator with oxygen; an explosion could result if oil and oxygen mix
- D. Only fill the accumulator with an inert gas such as dry nitrogen, because dry nitrogen is free of water vapor and oxygen

(NOTE: Allowing water vapor to enter the accumulator can cause the accumulator to rust.)

- E. Do not use compressed air in an accumulator
- F. Before disassembling an accumulator release both gas and hydraulic pressures
- G. Use extreme care in removing the springs from spring-loaded accumulators

### VI. Reasons for using a cooler

- A. To prevent power losses (inefficiencies) in various hydraulic components such as pumps, valves, and lines
- B. To prevent excessive operating temperatures
- C. To remove heat from the hydraulic system and increase component life

### VII. Types of coolers (Transparencies 3 and 4)

- A. Air-cooled cooler — Uses moving air past a radiator to dissipate the heat
- B. Water-cooled cooler — Uses water flowing through tubes immersed in the oil to remove the heat

### VIII. Components of an air-cooled cooler and their functions

- A. Top tank — Holds incoming hot hydraulic fluid
- B. Core — A radiator-like device over which air passes to cool the hydraulic fluid

(NOTE: Air-cooled coolers must be located in front of the engine radiator to assure a steady supply of air.)

- C. Bypass valve — Located between the top and bottom tanks to protect the cooler from excessive pressure build-up during cold weather starting, and dumps fluid into the main pump when a closed-center system is depleted of fluid

Example: Single-acting cylinder operation

- D. Bottom tank — Holds cooled hydraulic fluid

## INFORMATION SHEET

### IX. Common failures of coolers

- A. Cooling fins on air-cooled models become clogged with dirt and debris
- B. Water tubes on water-cooled models become plugged with sediment
- C. Water leaks into fluid
- D. Fluid leaks into water

### X. Reasons for using a heater

- A. The viscosity of hydraulic fluid is sensitive to temperature; at cold temperatures the fluid is thick and large pressure losses can occur in the lines
- B. In cold environments heaters are often used to help raise the temperature to the desired operating temperature or to help maintain the desired operating temperature

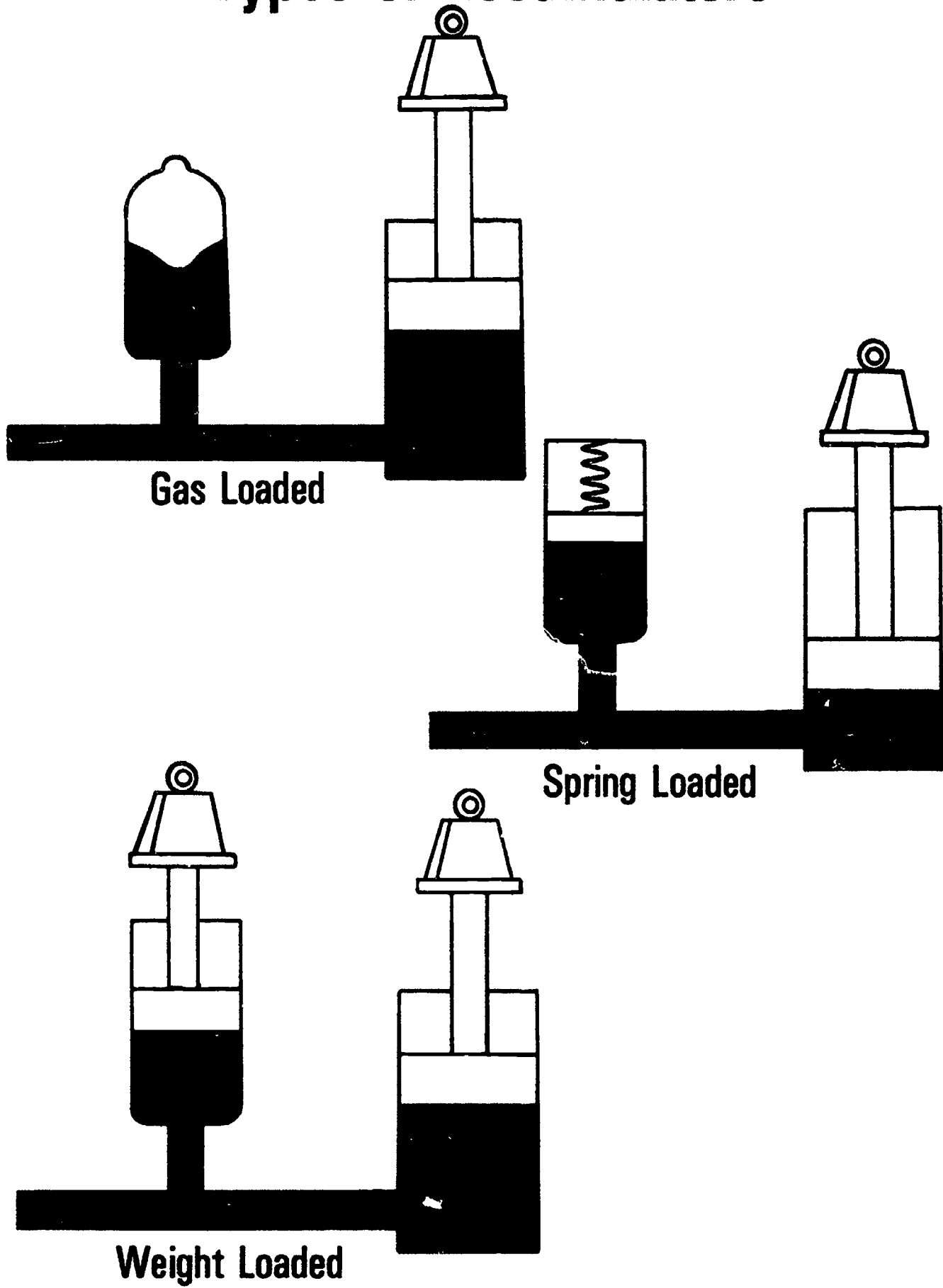
### XI. Types of heaters

- A. Electric — Uses electric heating element to add heat to the system
- B. Heat exchangers — Uses the same principle as a cooler, except instead of removing heat, hot air or liquid is used to add heat

### XII. Common failures of heaters

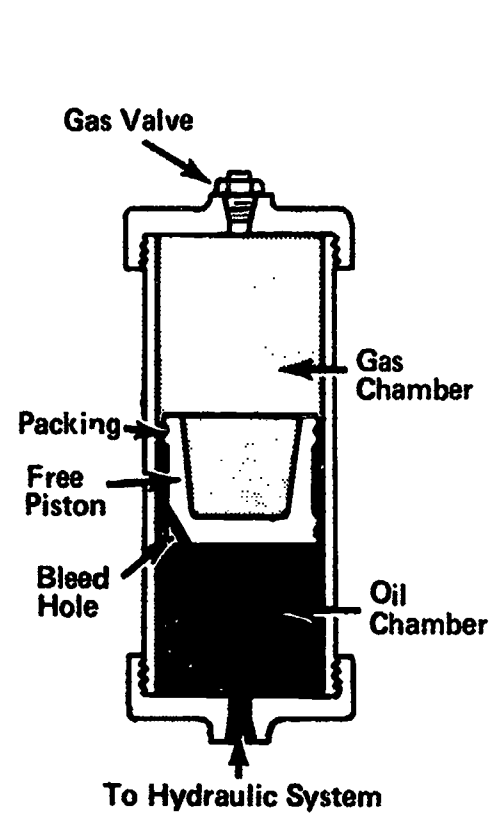
- A. Electrical heating element fails
- B. Heat exchanger fails (see above)

# Types of Accumulators

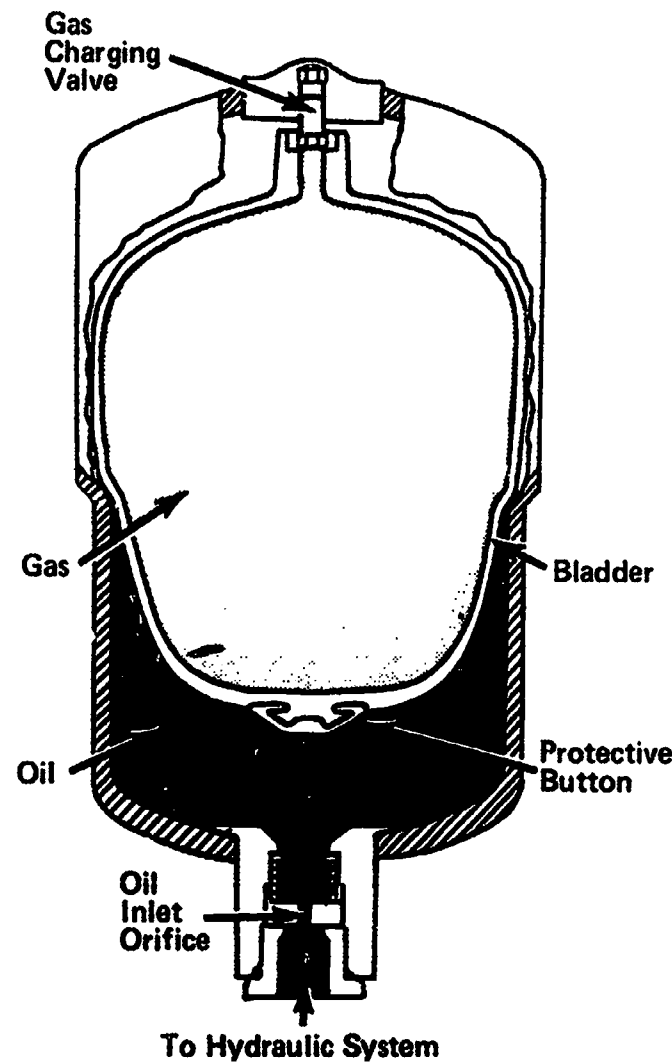




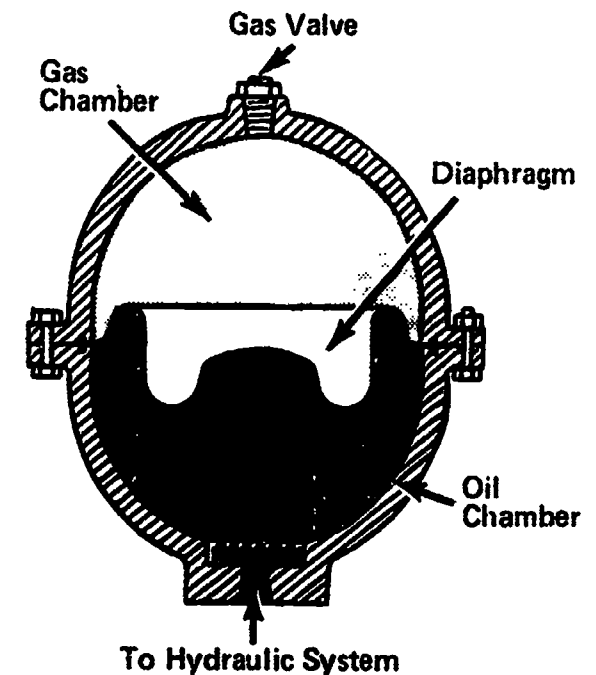
# Types of Gas-Loaded Accumulators



**Piston-Type Accumulator**

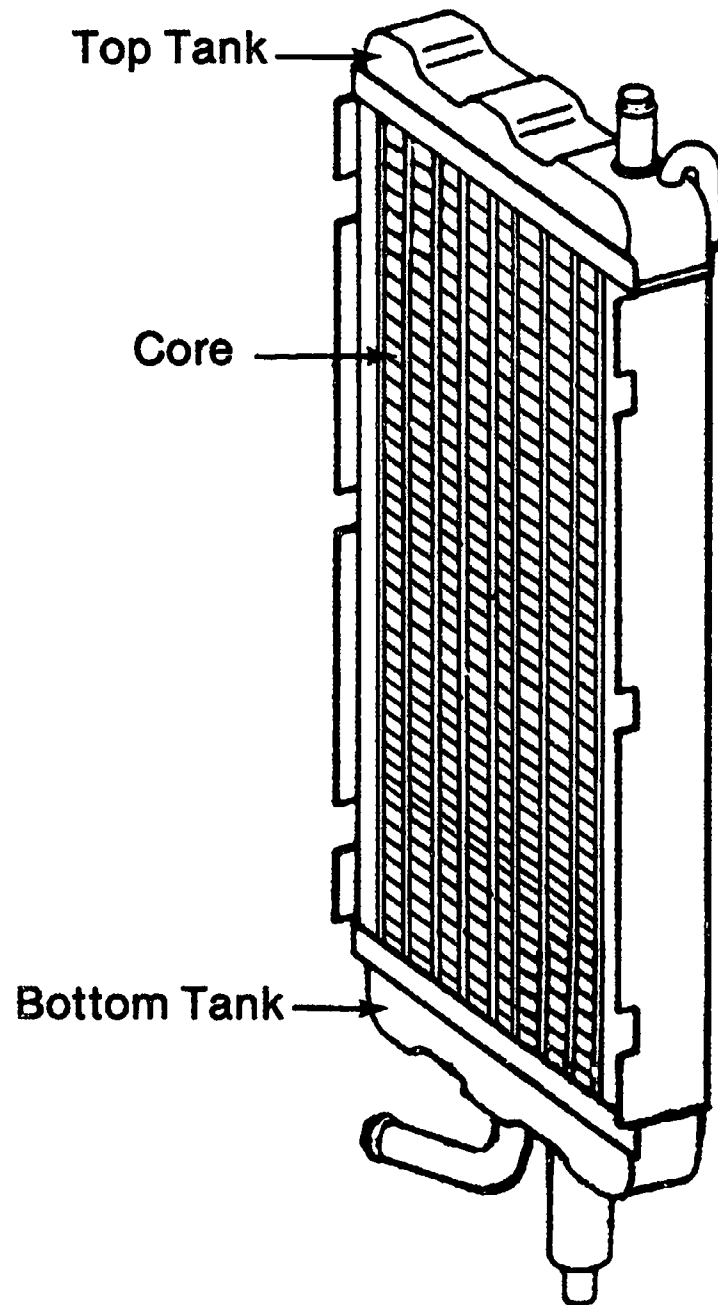


**Bladder-Type Accumulator in Operation**

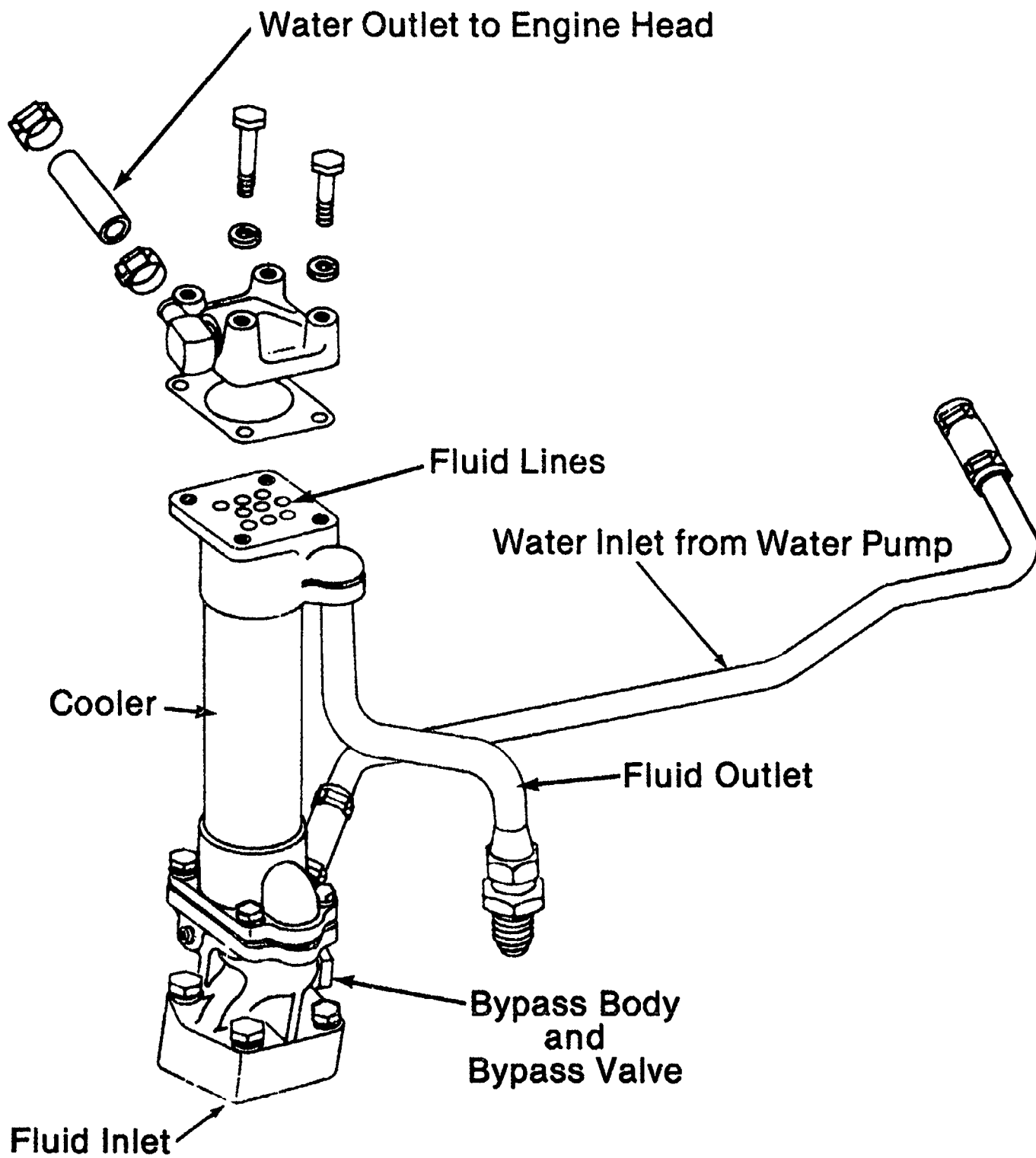


**Diaphragm-Type Accumulator**

# Air-Cooled Cooler



# Water-Cooled Cooler



## **ACCESSORIES UNIT XI**

### **JOB SHEET #1 — INSPECT, CLEAN, AND TEST AN AIR-COOLED COOLER**

#### **A. Tools and materials**

1. Air-cooled cooler
2. Hand tool set
3. Service manual, if available
4. Solvent
5. Lint free shop towels
6. Safety glasses
7. Caps for covering fluid ports
8. Hydraulic power supply capable of providing hydraulic fluid at the rated pressure and flow capacity of the cooler  
  
(NOTE: The power supply should have a load valve in the return line.)
9. Pressurized air supply
10. Water tank

#### **B. Routine #1 — Clean the cooler**

1. Install caps to cover the fluid ports
  2. Remove any caked-on dirt and mud from outside of the cooler
  3. Use solvent to remove any residual grease or films from external surfaces
  4. Allow solvent to dry
  5. Remove the caps on the fluid ports
  6. Flush the unit with solvent
- ☐ Have your instructor check your work

**JOB SHEET #1****C. Routine #2 — Inspect the cooler**

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
1. Examine external welds and joints for any signs of cracking		
2. Examine fins for damage		
3. Examine the fittings for damage		

☐ Have your instructor check your work

**D. Routine #3 — Inspect the cooler**

1. Connect the cooler to the hydraulic power supply
2. Slowly increase the pressure on the inlet side of the cooler until rated pressure is attained by slowly closing the load valve
3. Examine the cooler for leaks, paying close attention to the area near weld, joints and fluid fittings
4. Note any leaks
5. Open the load valve
6. Supply the cooler with fluid flow at flow rate equal to its rated capacity
7. Allow the fluid to circulate until operating temperature is reached
8. Measure the differential pressure across the cooler with rated flow rate
9. Record and compare to manufacturer's specifications

(NOTE: Excessive differential pressure is an indication of internal blockage. If pressure is too great examine internal surfaces for blockage.)

☐ Have your instructor check your work

**JOB SHEET #1****E. Routine #4 — Inspect the cooler with alternate inspection routine**

(NOTE: In situations where a hydraulic power supply is not present, this routine can be used to effectively inspect a cooler.)

1. Remove the cooler from the system
2. Drain all hydraulic fluid from the system
3. Plug the outlet of the bottom tank with a short piece of hose with a pressure plug in it

(NOTE: The plug must be capable of holding about 120 pounds of pressure.)

4. Submerge the cooler in a water tank
5. Connect the air supply to the inlet line of the top tank
6. Activate the air supply and watch the water for bubbles that indicate leaks in the system
7. Continue test until certain there are no leaks or until all leaks have been isolated
8. Repair leaks as required or replace cooler if damage is beyond repair

(NOTE: Leaks in the fin-like cooling structure can be repaired at a radiator shop, and the core and both tanks can be repaired with either soldering or brazing.)

☐ Have your instructor check your work

9. Reinstall all components
10. Clean up area and return tools and equipment to proper storage

## ACCESSORIES UNIT XI

### JOB SHEET #2 — INSPECT, CLEAN, AND TEST A HEATER

**A. Tools and materials**

1. Thermostatically controlled electric heater
2. Hand tool set
3. Service manual, if available
4. Solvent
5. Lint free shop towels
6. Safety glasses
7. A container of hydraulic fluid large enough to accommodate the heater
8. Thermometer
9. Fire extinguisher

**B. Procedures**

1. Clean — Use the solvent to remove any film buildup on the shell of the heater
2. Inspect

(NOTE: After completing each point in this inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Examine the shell for any cracks		
b. Examine the electric connections to insure the terminals are not damaged or corroded		
c. Examine the heating element area for any leaks which will allow fluid to enter this area		

**JOB SHEET #2****3. Test**

(NOTE: This must be done only under instructor's supervision.)

(CAUTION: *Do not* touch bare wires.)

- a. Insert the heater into the container of hydraulic fluid

(NOTE: Only the heating element portion should be immersed. Power should never be applied to the heater when not immersed.)

- b. Apply power

- c. Observe the fluid temperature

(NOTE: It should slowly rise until the thermostat setting is reached. The heater should then turn off. This can often be heard. The temperature should get no higher than approximately 10°F greater than the thermostat setting. If the temperature continues to rise then the thermostat is not functioning properly.)

- ☐ Have your instructor check your work

4. Clean up area and return tools and materials to proper storage



# ACCESSORIES UNIT XI

NAME \_\_\_\_\_

## TEST

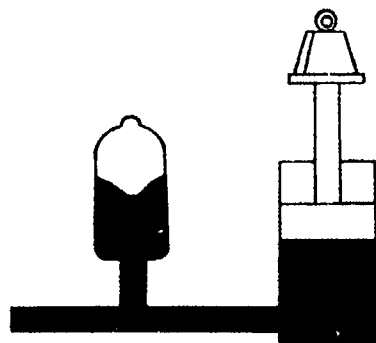
1. Define terms associated with accessories.

- a. Accumulator — \_\_\_\_\_  
 \_\_\_\_\_
- b. Heat exchanger — \_\_\_\_\_  
 \_\_\_\_\_
- c. Heater — \_\_\_\_\_  
 \_\_\_\_\_
- d. Thermostat — \_\_\_\_\_  
 \_\_\_\_\_

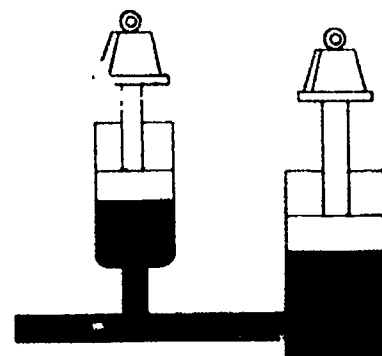
2. Select functions of an accumulator by placing an "X" in the appropriate blanks.

- \_\_\_\_a. Provides cooling for the system
- \_\_\_\_b. Absorbs shock
- \_\_\_\_c. Allows the system to build pressure gradually
- \_\_\_\_d. Stores energy
- \_\_\_\_e. Filters dirt particles
- \_\_\_\_f. Maintains pressure

3. Identify the types of accumulators.

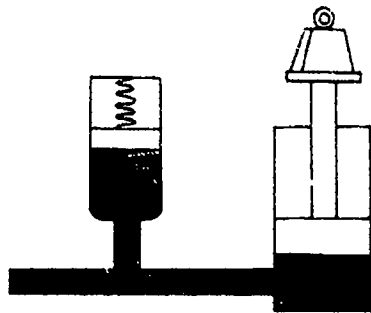


a. \_\_\_\_\_



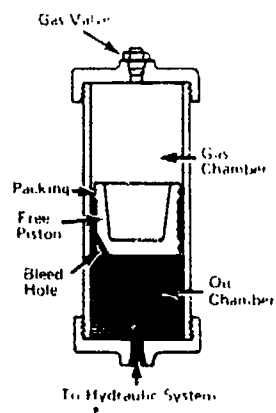
b. \_\_\_\_\_

## TEST

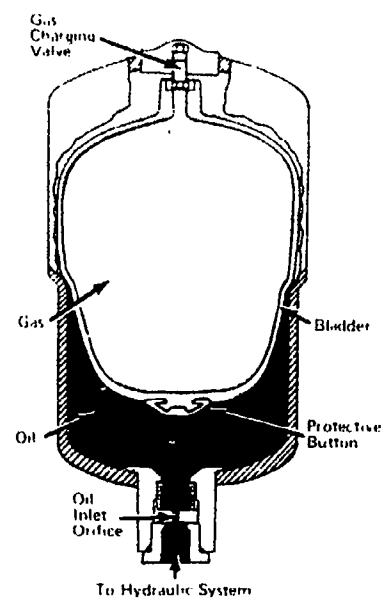


c. \_\_\_\_\_

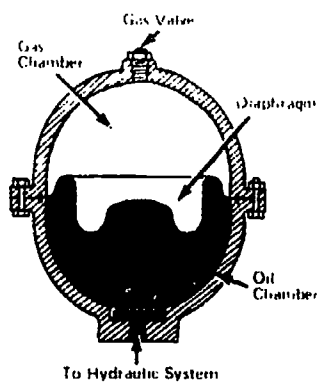
4. Identify the types of gas-loaded accumulators.



a. \_\_\_\_\_



b. \_\_\_\_\_



c. \_\_\_\_\_

## TEST

5. List five safety precautions for working with accumulators.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_

6. Explain reasons for using a cooler.

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7. Describe types of coolers.

- a. Air-cooled cooler — \_\_\_\_\_  
\_\_\_\_\_
- b. Water-cooled cooler — \_\_\_\_\_  
\_\_\_\_\_

8. Match components of an air-cooled cooler with their functions.

- |         |   |                 |
|---------|---|-----------------|
| _____a. | Holds incoming hot hydraulic fluid  | 1. Core         |
| _____b. | A radiator-like device over which air passes to cool the hydraulic fluid  | 2. Bottom tank  |
| _____c. | Located between the top and bottom tanks to protect the cooler from excessive pressure build-up during cold weather starting, and dumps fluid into the main pump when a closed-center system is depleted of fluid | 3. Top tank     |
| _____d. | Holds cooled hydraulic fluid  | 4. Bypass valve |

**TEST**

9. List three common failures of coolers.
- a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
10. Explain reasons for using a heater.
- a. \_\_\_\_\_  
\_\_\_\_\_
  - b. \_\_\_\_\_  
\_\_\_\_\_
11. Describe two types of heaters.
- a. Electric — \_\_\_\_\_  
\_\_\_\_\_
  - b. Heat exchanger — \_\_\_\_\_  
\_\_\_\_\_
12. List two common failures of heaters.
- a. \_\_\_\_\_
  - b. \_\_\_\_\_
- (NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)
13. Demonstrate the ability to:
- a. Inspect, clean, and test an air-cooled cooler.
  - b. Inspect, clean, and test a heater.

## ACCESSORIES UNIT XI

### ANSWERS TO TEST

1.
  - a. A device for storing hydraulic energy
  - b. A device for removing heat from hydraulic fluids
  - c. A device for adding heat to hydraulic fluids
  - d. An automatic device for regulating temperature
2. b, c, d, f
3.
  - a. Gas-loaded accumulator
  - b. Weight-loaded accumulator
  - c. Spring-loaded accumulator
4.
  - a. Piston type
  - b. Bladder type
  - c. Diaphragm type
5. Any five of the following:
  - a. *Always* discharge stored hydraulic fluid from the accumulator prior to removing it from the system
  - b. Never charge an accumulator to a pressure more than that recommended by the manufacturer
  - c. *Never* fill an accumulator with oxygen; an explosion could result if oil and oxygen mix
  - d. Only fill the accumulator with an inert gas such as dry nitrogen, because dry nitrogen is free of water vapor and oxygen
  - e. Do not use compressed air in an accumulator
  - f. Before disassembling an accumulator release both gas and hydraulic pressures
  - g. Use extreme care in removing the springs from spring-loaded accumulators
6. Explanation should include:
  - a. To prevent power losses in various hydraulic components, such as pumps, valves, and lines
  - b. To prevent excessive operating temperatures
  - c. To remove heat from the hydraulic system and increase component life
7. Description should include:
  - a. Uses moving air past a radiator to dissipate the heat
  - b. Uses water flowing through tubes immersed in the oil to remove the heat
8.
  - a. 3
  - b. 1
  - c. 4
  - d. 2

**ANSWERS TO TEST**

9. Any three of the following:
  - a. Cooling fins on air-cooled models become clogged with dirt and debris
  - b. Water tubes on water-cooled models become plugged with sediment
  - c. Water leaks into fluid
  - d. Fluid leaks into water
10. Explanation should include:
  - a. The viscosity of hydraulic fluid is sensitive to temperature; at cold temperatures the fluid is thick and large pressure losses can occur in the lines
  - b. In cold environments heaters are often used to help raise the temperature to the desired operating temperature or to help maintain the desired operating temperature
11. Description should include:
  - a. Electric — Uses electric heating element to add heat to the system
  - b. Heat exchanger — Uses the same principle as a cooler, except instead of removing heat, hot air or liquid is used to add heat
12.
  - a. Electrical heating element fails
  - b. Heat exchanger fails
13. Performance skills evaluated to the satisfaction of the instructor

# **HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS**

## **UNIT XII**

### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to select true statements concerning the fluid flow in an open-center circuit and a multiple actuator open-center system and identify symbols used in a hydraulic schematic and symbols for various directional control valves. The student should also be able to draw a schematic of an open-center and closed-center system and an open-center hydraulic circuit. This knowledge will be evidenced by correctly performing the procedures outlined in the assignment sheets and by scoring 85 percent on the unit test.

### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Match terms related to hydraulic circuits, diagrams, and symbols with their correct definitions.
2. Identify the components of a basic hydraulic circuit.
3. Distinguish between types of hydraulic circuits.
4. Complete statements concerning advantages and disadvantages of open-center and closed-center systems.
5. Select true statements concerning fluid flow in an open-center circuit.
6. Select true statements concerning fluid flow in multiple actuator open-center systems.
7. Distinguish between descriptions of valves in the neutral and shifted positions in the fluid flow in a closed-center system.
8. Identify the symbols used in a hydraulic schematic.
9. Identify the symbols for various directional control valves.
10. Draw a schematic of an open-center and a closed-center system.
11. Draw an open-center hydraulic circuit. (Assignment Sheet #1)
12. Show the oil flow in a circuit. (Assignment Sheet #2)

## **HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS UNIT XII**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and assignment sheets.
- C. Make transparencies.
- D. Discuss unit and specific objectives.
- E. Discuss information and assignment sheets.
- F. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency masters
  - 1. TM 1 — Components of a Basic Hydraulic Circuit
  - 2. TM 2 — Types of Hydraulic Circuits
  - 3. TM 3 — Fluid Flow in an Open-Center Circuit
  - 4. TM 4 — Fluid Flow in a Multiple Actuator Open-Center Series Circuit
  - 5. TM 5 — Fluid Flow in an Open-Center Series-Parallel Circuit
  - 6. TM 6 — Fluid Flow in Closed-Center Systems
  - 7. TM 7 — Hydraulic Schematic Symbols
  - 8. TM 8 — Directional Control Valve Symbols
  - 9. TM 9 — Schematic Representations of Hydraulic Circuits
- D. Assignment sheets
  - 1. Assignment Sheet #1 — Draw an Open-Center Hydraulic Circuit
  - 2. Assignment Sheet #2 — Show the Oil Flow in a Circuit
- E. Test
- F. Answers to test



## REFERENCES USED IN DEVELOPING THIS UNIT

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1967.
- B. *Fluid Power 1*. Cleveland, OH 44112: Parker-Hannifin Corp., 1975.

# HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS

## UNIT XII

### INFORMATION SHEET

#### I. Terms and definitions

- A. Actuator — A device which converts hydraulic energy into mechanical force and motion  
  
Example: Hydraulic cylinders and motors
- B. Schematic — A simplified symbol which indicates essential characteristics applicable to all similar components
- C. Circuit — A series of component parts connected to each other by fluid lines or passages; the complete path of flow
- D. Symbol — A representation of the characteristics of a hydraulic component by means of lines on a flat surface
- E. Port — Inlet or outlet connection on a valve
- F. Load check — A check valve which is used to support the load in the event a line breaks or the engine dies; also used to keep a load from momentarily dropping when it is initially started to raise
- G. Check valve — A valve which permits flow only in one direction
- H. Float position — A position on a directional control valve which allows the load to move freely or float
- I. Regenerative valve — A valve which allows the oil to flow from one side of a cylinder to the other when the load is dropped

(NOTE: This allows the load to drop quicker, because the pump does not have to supply all of the fluid. This valve is also called a quick drop valve.)

#### II. Components of a basic hydraulic circuit (Transparency 1)

- A. Reservoir
- B. Pump
- C. Control valve

(NOTE: Some circuits may not have a control valve.)

- D. Actuator
  - 1. Cylinder
  - 2. Motor

## INFORMATION SHEET

### E. Lines

(NOTE: The relief valve shown on Transparency 1 is for limiting the hydraulic pressure in the system and is essential for this particular circuit, but not all circuits will have a similar valve.)

### III. Types of hydraulic circuits (Transparency 2)

#### A. Open-center

1. Constant flow system
2. Oil flows continuously from the pump

#### B. Closed-center

1. Constant pressure system
2. Pump maintains a constant pressure in the system
3. Flow from pump is varied to satisfy the requirements of the rest of the circuit

### IV. Advantages and disadvantages of open-center and closed-center systems

#### A. Advantages of open-center systems

1. Less wear on pump parts because of continuous flow, but not continuous pressure
2. No constant pressure on hoses, steel lines, and connectors

#### B. Disadvantages of open-center systems

1. Systems are not responsive to demands for immediate pressure
2. Units such as brakes and steering are not as responsive as in closed-center systems

#### C. Advantages of closed-center systems

1. All components are more responsive than with open-center systems
2. Systems can facilitate more remote valves that can be operated simultaneously

Example: A tractor with a loader that can raise and tilt quickly at the same time; open-center systems are much slower in multi-task operations

## INFORMATION SHEET

### D. Disadvantages of closed-center systems

1. Excessive pump wear
2. Constant system pressure subjects components to stress

### V. Fluid flow in an open-center circuit (Transparency 3)

(NOTE: The term "open-center" comes from the fact that in the valve's neutral (or center) position the passage is open to return flow to the reservoir.)

#### A. There is constant flow from the reservoir to the pump to the rest of the system

(NOTE: Fixed displacement pumps are used for open-center systems. Gear pumps are often used but fixed displacement vane or piston pumps can also be used.)

#### B. Fluid flows to the control valve

1. If the valve is in the neutral position, then the fluid is returned to the reservoir
2. If the valve is shifted, then the fluid is diverted to the actuator (cylinder)

(NOTE: Fluid returned from the actuator is returned through the control valve to the reservoir.)

#### C. If the pressure of the system exceeds the setting of the relief valve a portion of the flow from the pump will be diverted back to the reservoir

(NOTE: The amount of flow diverted will be sufficient to insure that the system pressure does not exceed the relief valve setting.)

### VI. Fluid flow in multiple actuator open-center systems (Transparency 4)

(NOTE: Open-center systems are often used for controlling more than one actuator. A typical example is a backhoe.)

#### A. Series connection

1. In the neutral position the fluid passes through the valves in series
2. When one valve is shifted the fluid is diverted to the actuator
3. The return flow from the actuator is then routed to the inlet of the next valve
4. In this configuration the first valve has priority over the next valve, etc.

## INFORMATION SHEET

### B. Series-parallel connection (Transparency 5)

1. Similar to the series connection, except when a valve is shifted the open-center neutral is closed and the fluid is available to all of the valves in parallel
2. If two valves are shifted at the same time the actuator requiring the least pressure will receive the flow (rather than the first valve)
3. If two actuators require approximately the same pressure then both will be operated

(NOTE: An advantage of the series-parallel configuration is the ability to operate two actuators simultaneously, assuming that the pressure required is approximately equal.)

### VII. Fluid flow in a closed-center system (Transparency 6)

#### A. All valves in neutral position

1. There is no flow path from the outlet of the pressure-compensated pump to the reservoir
2. The pressure builds up at the outlet until the compensator pressure is reached and the pump "destrokes" (i.e., the pump displacement is zero) and no fluid is pumped from the pump

#### B. One or more valves shifted

1. The pressurized fluid is directed to the actuators, which causes a drop in the pump outlet pressure
2. The drop in compensator pressure causes the pump to "stroke" and increase the displacement until adequate flow is available to satisfy demands of all actuators

(NOTE: The pump displacement (and therefore flow) will be regulated by the compensator to maintain constant pressure on the outlet of the pump. This enables multiple actuators to operate simultaneously.)

### VIII. Symbols used in a hydraulic schematic (Transparency 7)

#### A. Pumps

1. Fixed displacement
2. Variable displacement
3. Pressure compensated

## INFORMATION SHEET

### B. Valves

1. Directional control
2. Pressure relief
3. Flow control
4. Check
5. Pilot operated check

### C. Reservoir

1. Vented
2. Pressurized

### D. Filter

### E. Motor

### F. Cylinder

### G. Heat exchanger

### H. Pressure gauge

### I. Temperature gauge

### J. Flowmeter

### K. Line

1. Not joined
2. Joining lines

## IX. Symbols for directional flow control valves (Transparency 8)

### A. Two-way, two position valve

### B. Four-way, two position valve

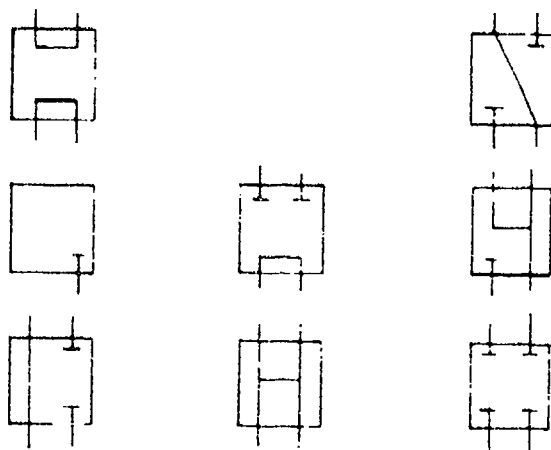
### C. Four-way, three position, open-center valve

## INFORMATION SHEET

- D. Four-way, three position, closed-center valve

(NOTE: Many variations on the center flow paths of a three position valve are common. Some are shown below in Figure 1.)

FIGURE 1

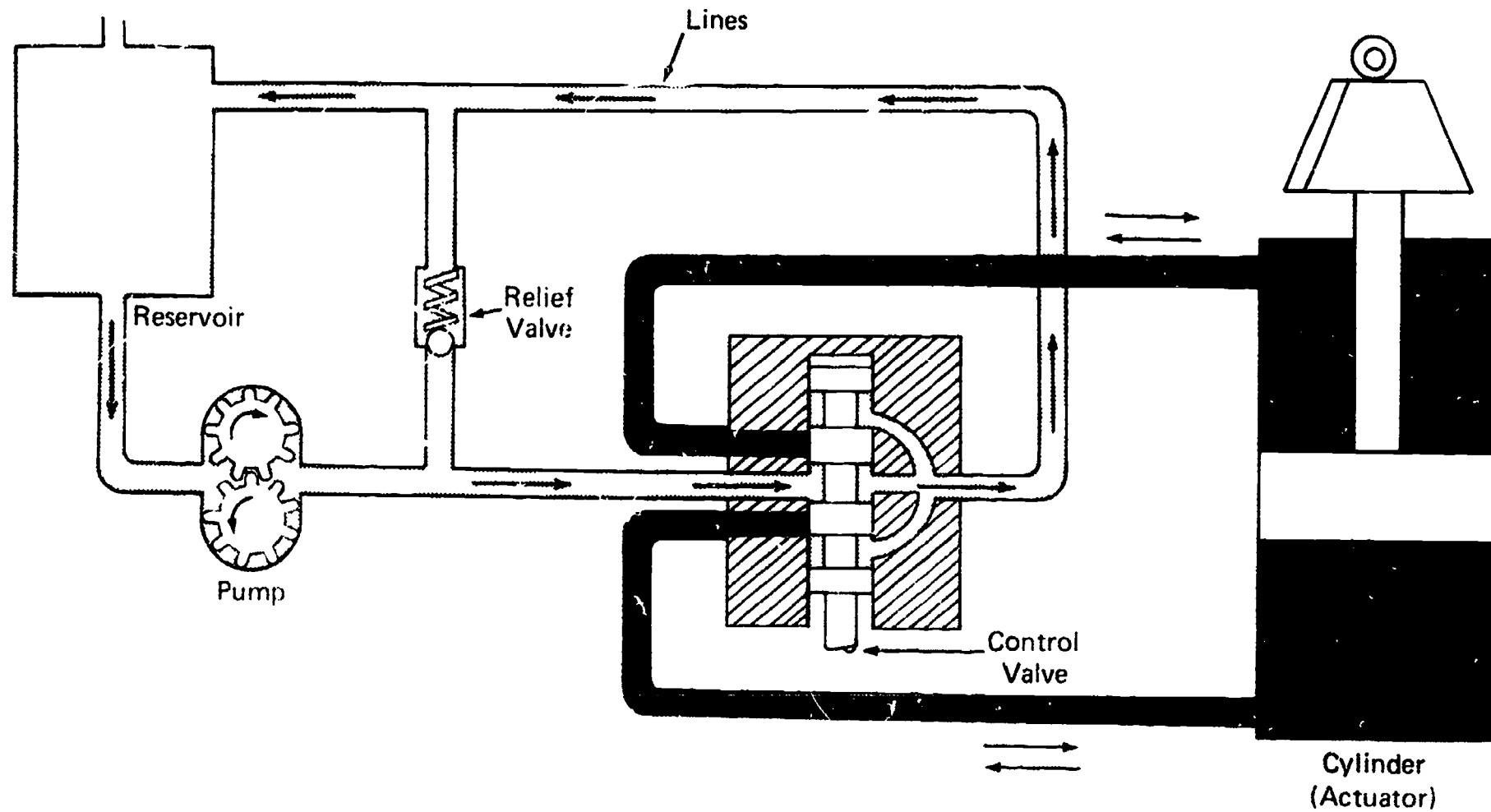


- X. Schematic representation of hydraulic circuits (Transparency 9)

- A. Open-center circuit
- B. Closed-center circuit

(NOTE. Transparency 9 is a schematic representation of Transparency 4.)

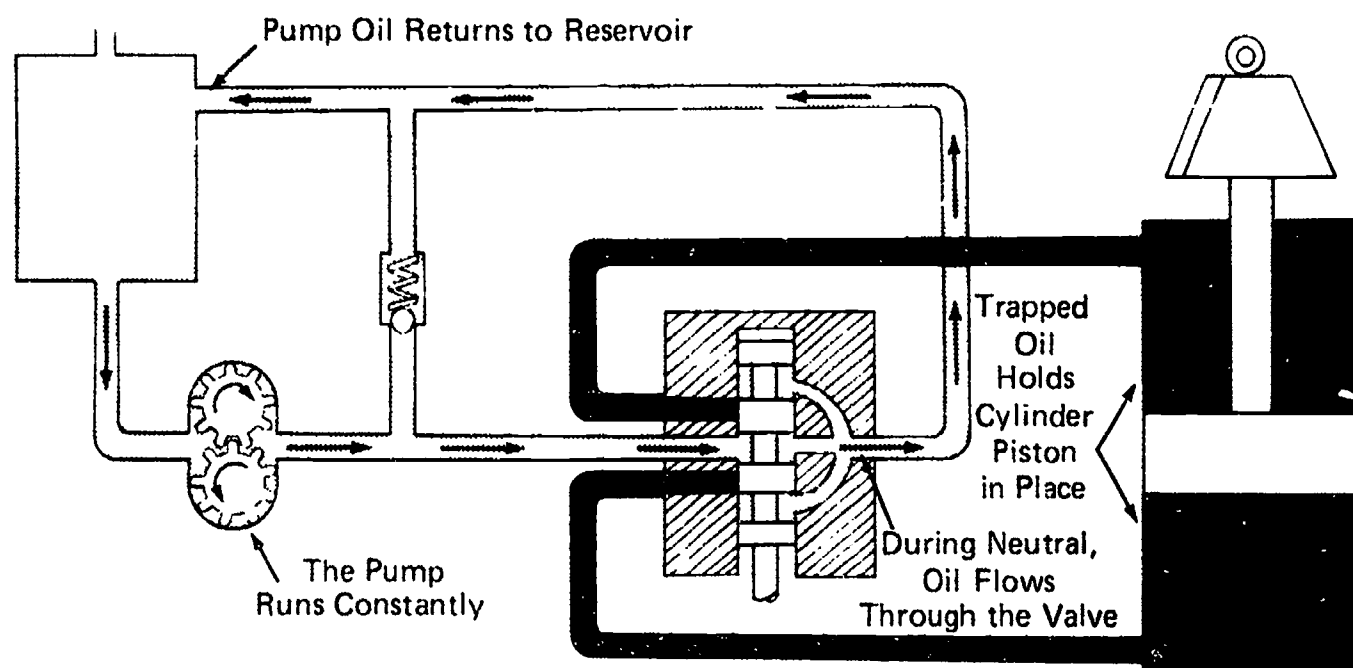
# Components of a Basic Hydraulic Circuit



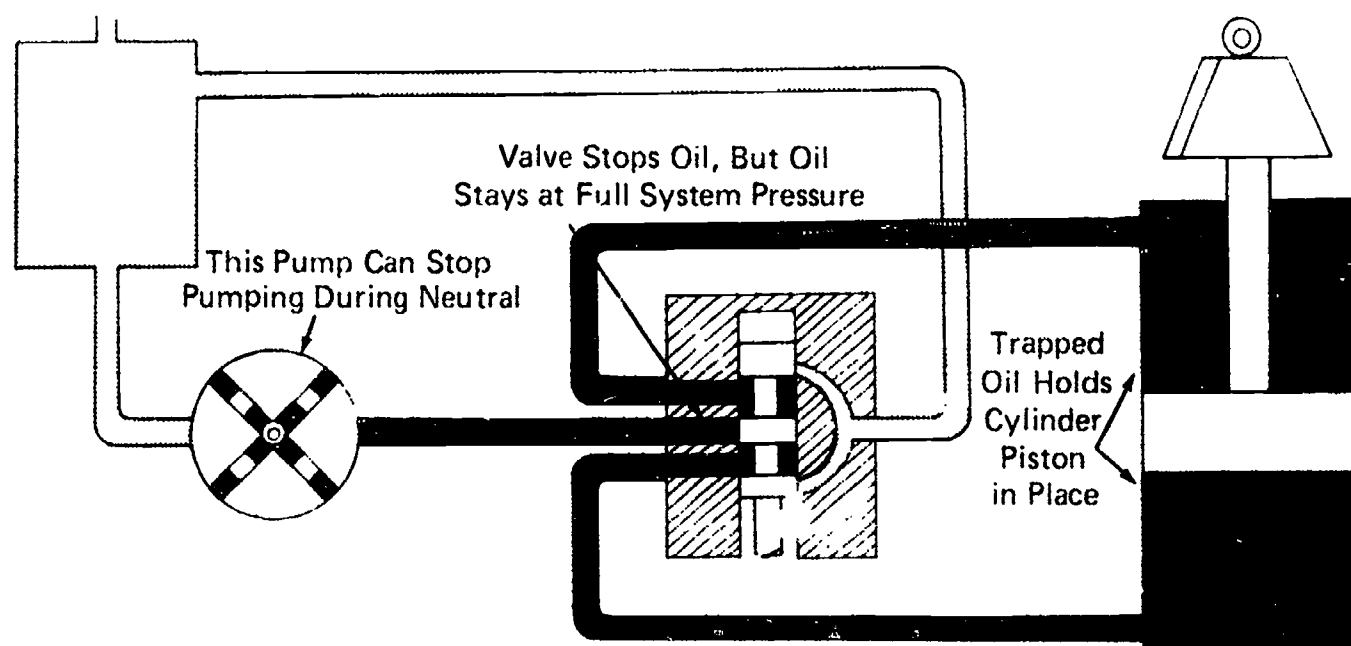


# Types of Hydraulic Circuits

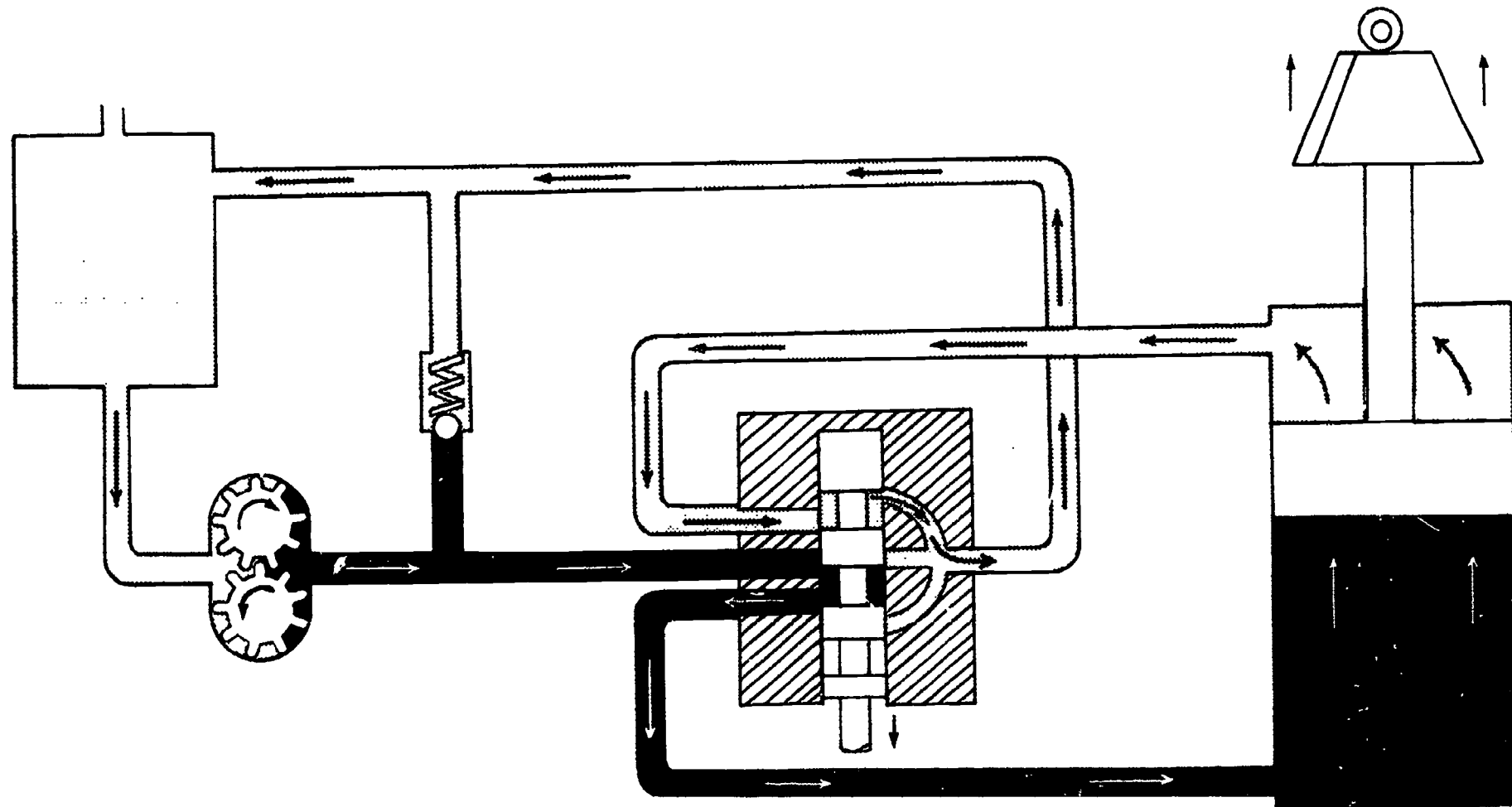
## Open-Center in Neutral



## Closed-Center in Neutral



# Fluid Flow in an Open-Center Circuit

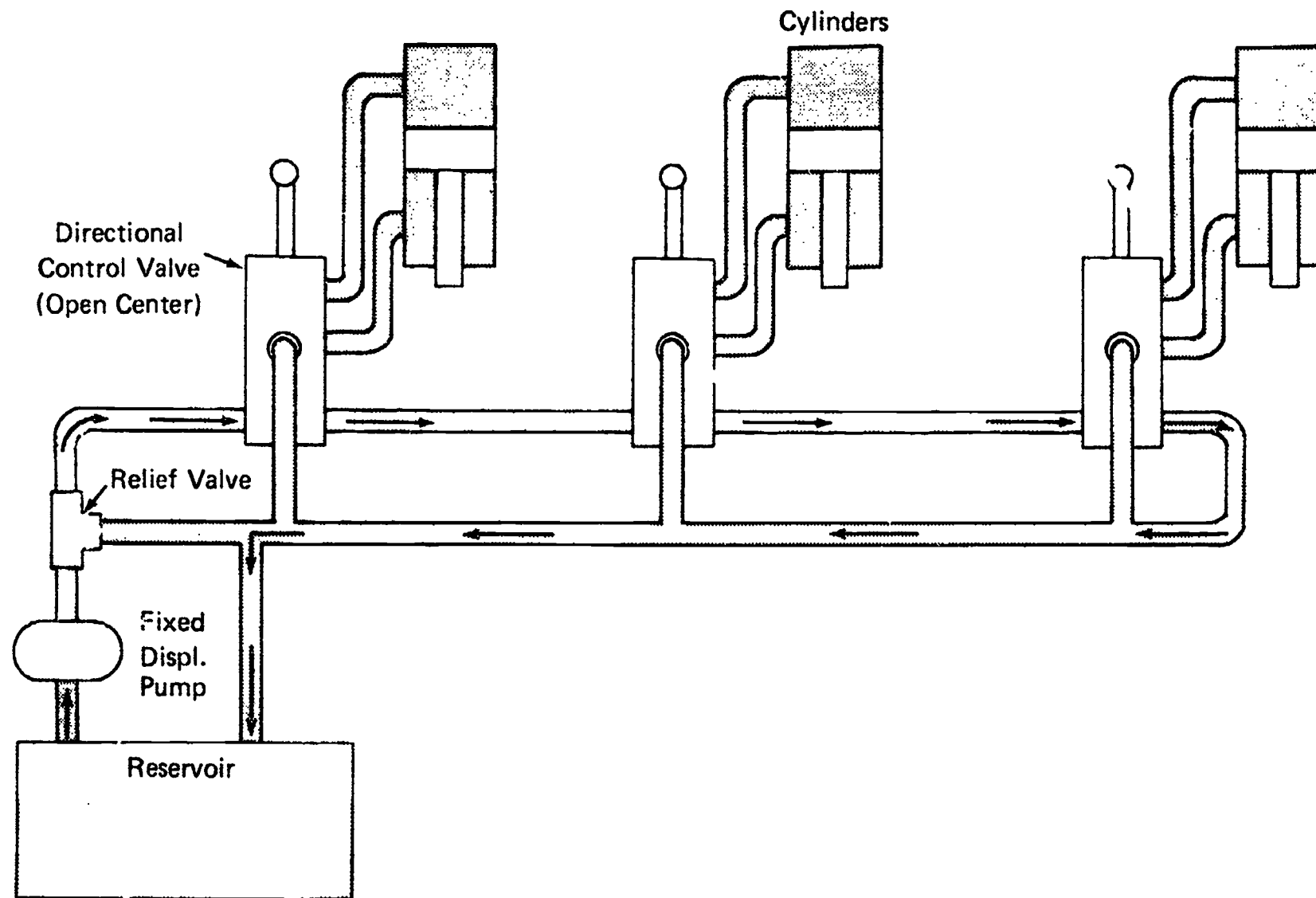


297

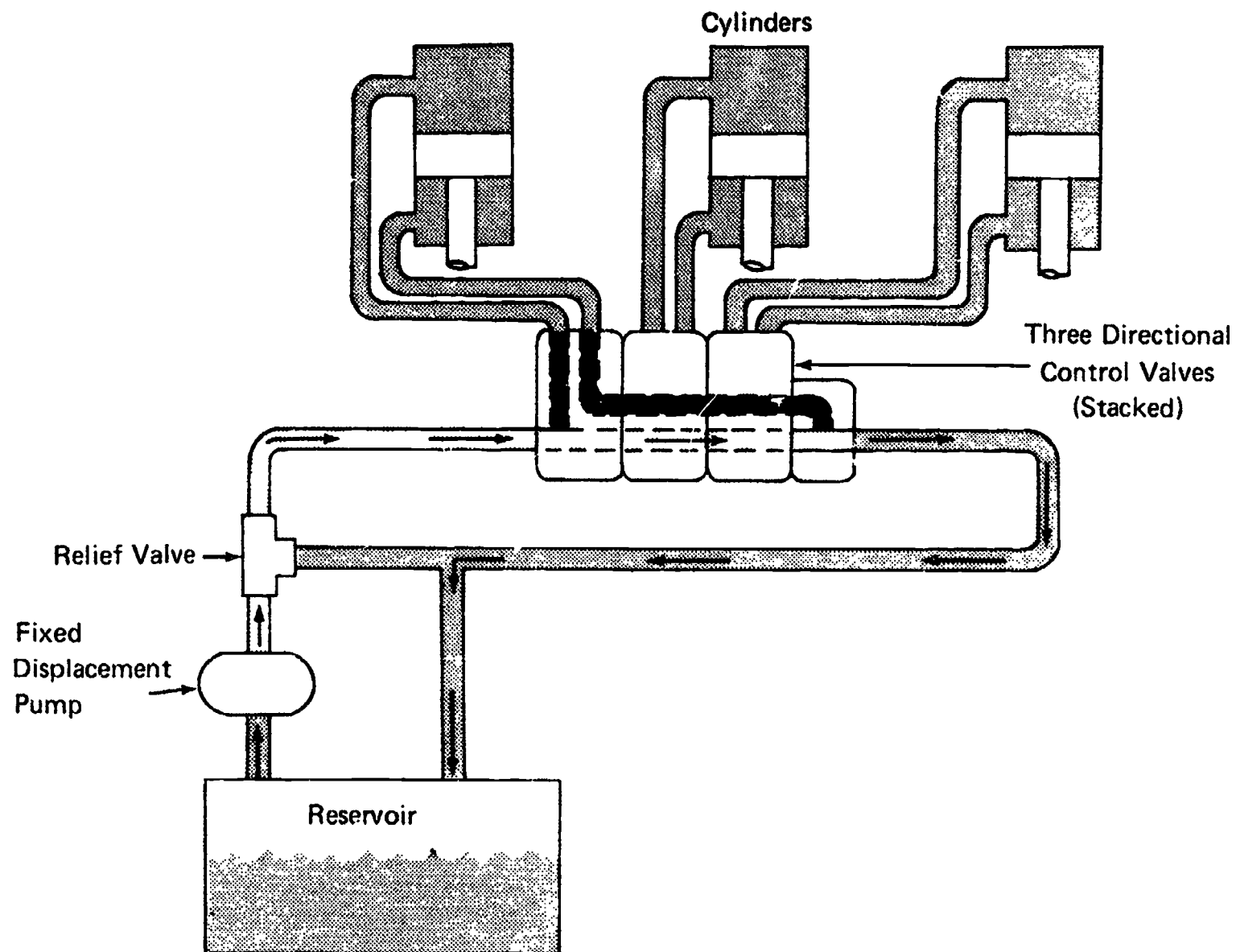
298

H-339

# Fluid Flow in a Multiple Actuator Open-Center Series Circuit



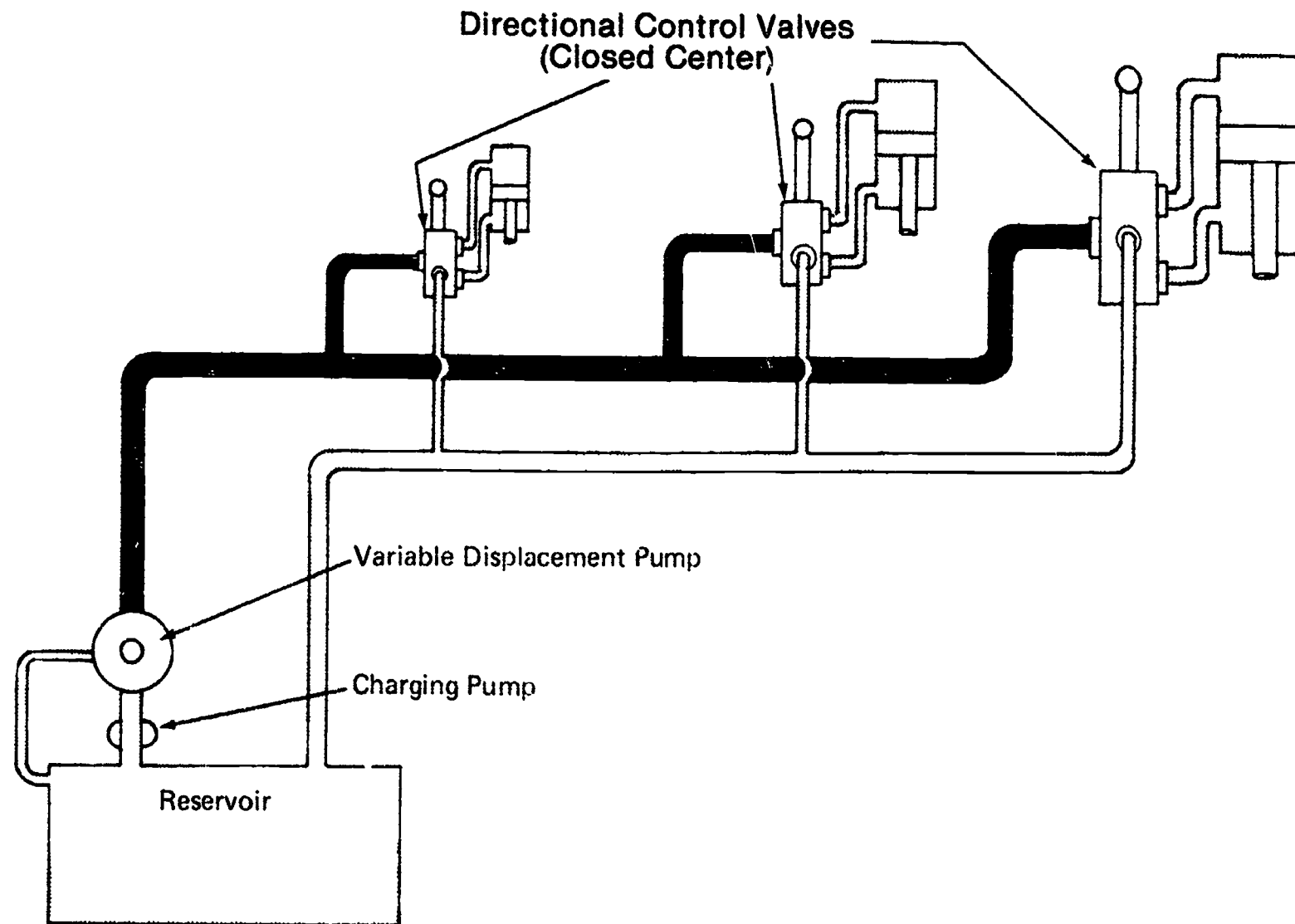
# Fluid Flow in an Open-Center Series-Parallel Circuit



302

301

# Fluid Flow in Closed-Center Systems



304

# Hydraulic Schematic Symbols



Fixed  
Displacement Pump



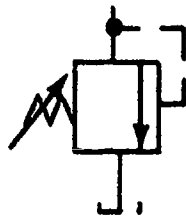
Variable  
Displacement Pump



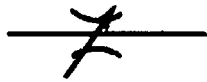
Pressure  
Compensated Pump



Directional Control Valve



Pressure Relief Valve



Flow Control Valve



Check Valve



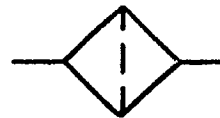
Pilot Operated Check Valve



Pressurized Reservoir



Vented Reservoir



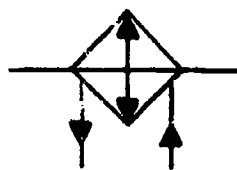
Filter



Motor



Cylinder



Heat Exchanger



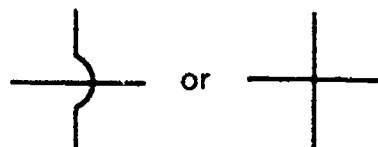
Pressure Gauge



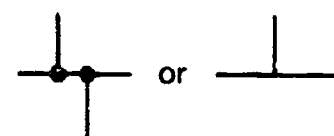
Temperature Gauge



Flowmeter

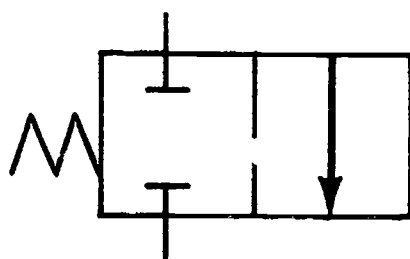


Lines not Joined

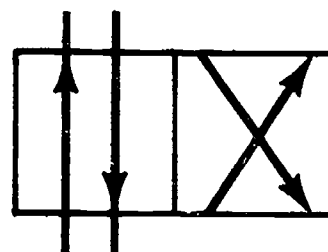


Joining Lines

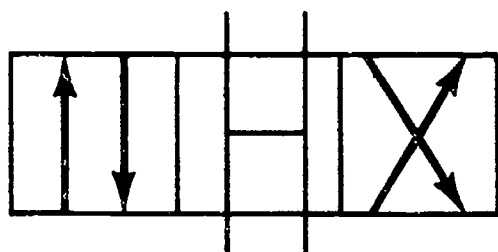
# Directional Control Valve Symbols



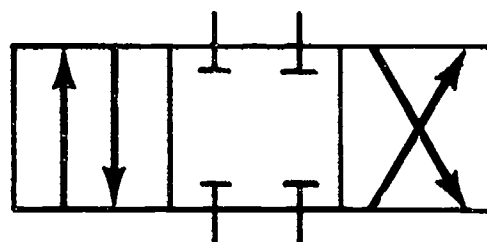
Two-way,  
two position valve



Four-way,  
two position valve

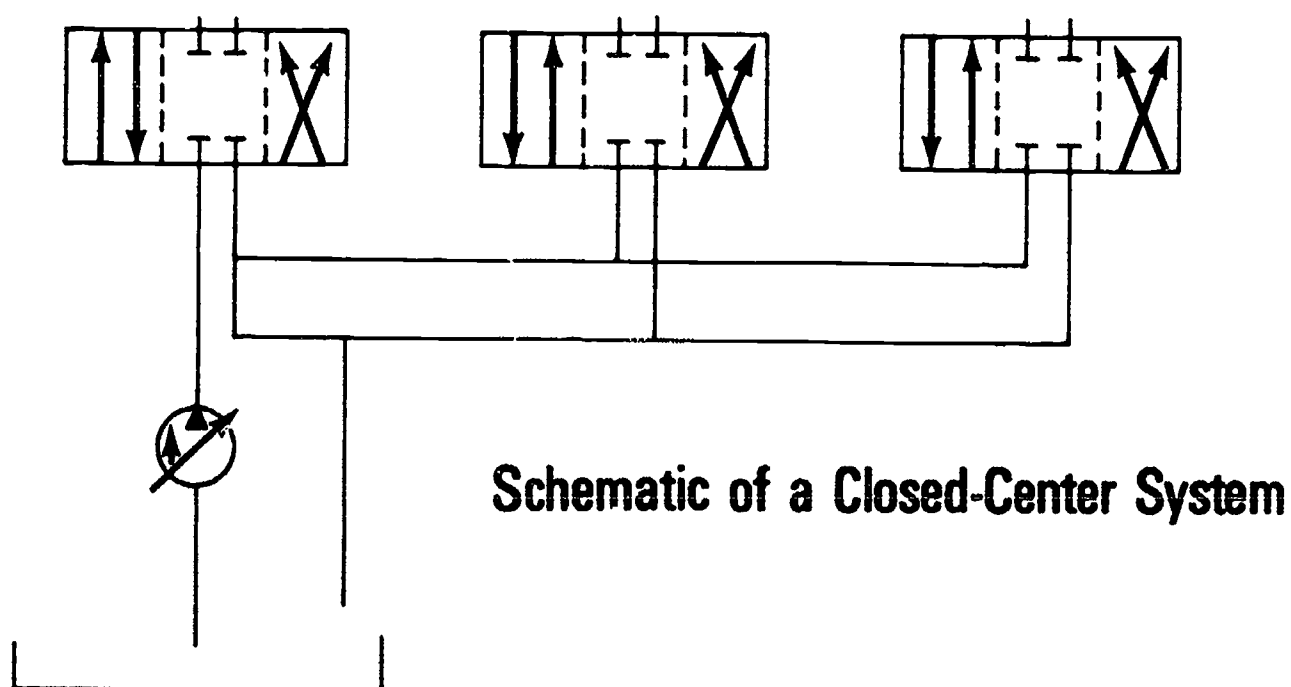
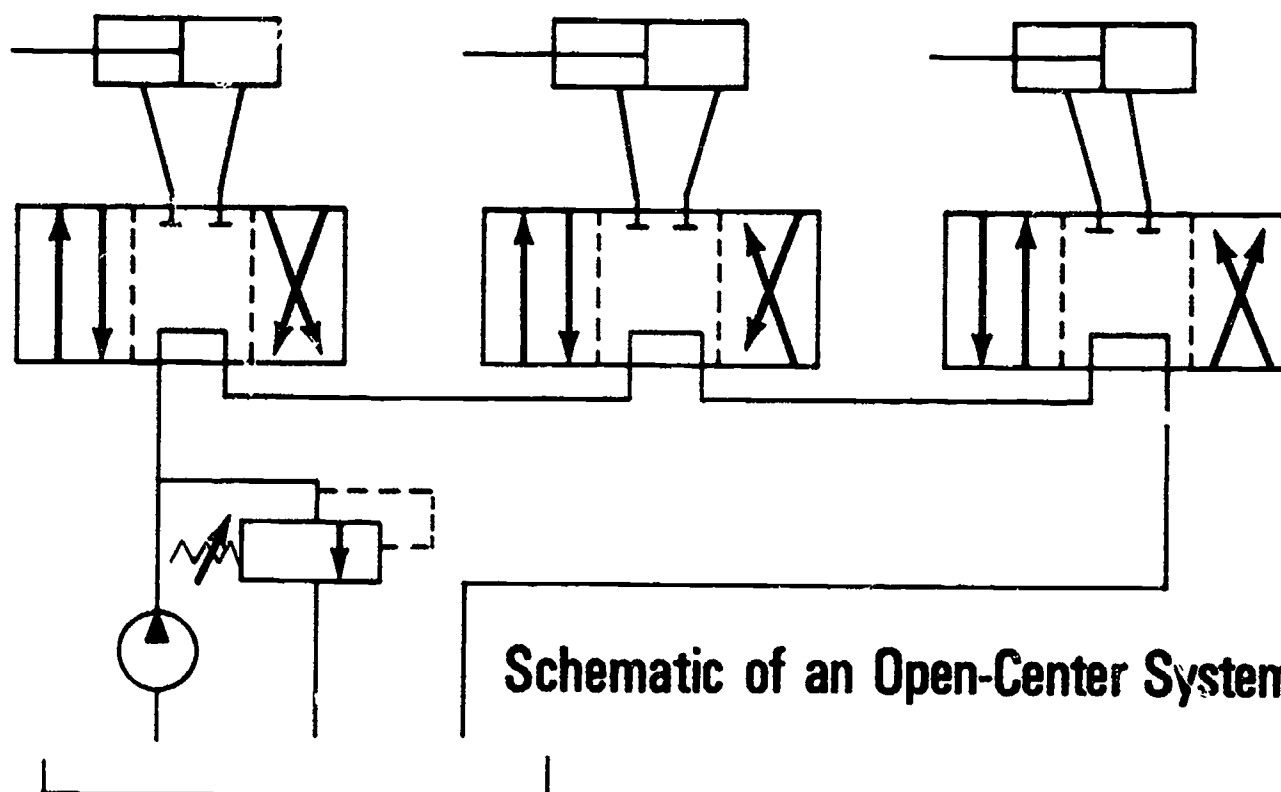


Four-way, three position  
open-center



Four-way, three position  
closed-center

# Schematic Representations of Hydraulic Circuits





## **HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS UNIT XII**

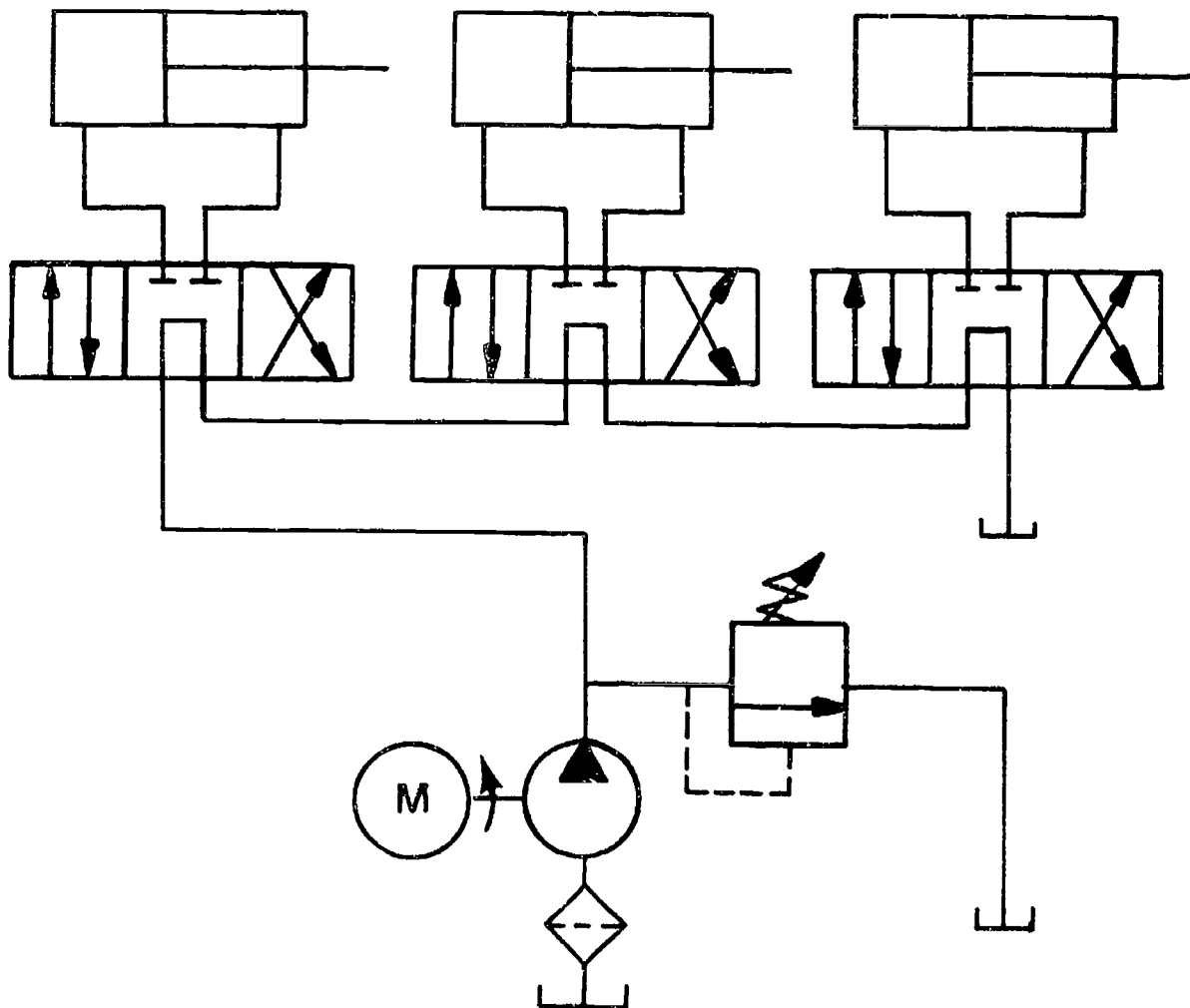
### **ASSIGNMENT SHEET #1 — DRAW AN OPEN-CENTER HYDRAULIC CIRCUIT**

Directions: Draw an open-center hydraulic circuit which uses a reservoir, lines, pumps, relief valve, 3 position 4 way directional control valve, and cylinder.

# HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS UNIT XII

## ASSIGNMENT SHEET #2 — SHOW THE OIL FLOW IN A CIRCUIT

Directions: Show the oil flow in this circuit when the middle valve has been shifted to the left.



# HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS

## UNIT XII

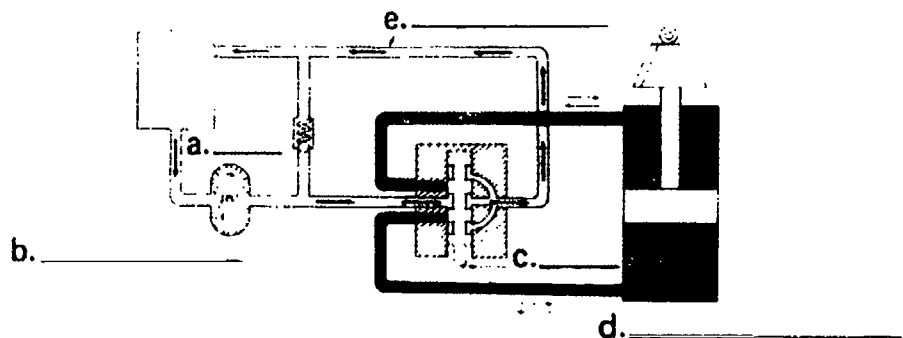
NAME \_\_\_\_\_

### TEST

1. Match the terms on the right with their correct definitions.

- |         |   |                       |
|---------|---|-----------------------|
| _____a. | A series of component parts connected to each other by fluid lines or passages; the complete path of flow   | 1. Port               |
| _____b. | A check valve which is used to support the load in the event a line breaks or the engine dies; also used to keep a load from momentarily dropping when it is initially started to raise | 2. Float position     |
| _____c. | Inlet or outlet connection on a valve   | 3. Schematic          |
| _____d. | A simplified symbol which indicates essential characteristics applicable to all similar components  | 4. Actuator           |
| _____e. | A valve which permits flow only in one direction  | 5. Regenerative valve |
| _____f. | A device which converts hydraulic energy into mechanical force and motion   | 6. Symbol             |
| _____g. | A representation of the characteristics of a hydraulic component by means of lines on a flat surface  | 7. Circuit            |
| _____h. | A position on a directional control valve which allows the load to move freely or float   | 8. Load check         |
| _____i. | A valve which allows the oil to flow from one side of a cylinder to the other when the load is dropped  | 9. Check valve        |

2. Identify the components of a basic hydraulic unit.



## TEST

3. Distinguish between types of hydraulic circuits by placing an "O" next to open center circuit descriptions and a "C" next to closed center circuit descriptions.
  - \_\_\_\_\_ a. Constant pressure system
  - \_\_\_\_\_ b. Flow from pump is varied to satisfy the requirements of the rest of the circuit
  - \_\_\_\_\_ c. Constant flow system
  - \_\_\_\_\_ d. Pump maintains a constant pressure in the system
  - \_\_\_\_\_ e. Oil flows continuously from the pump
  
4. Complete the following statements concerning advantages and disadvantages of open-center and closed-center systems by inserting the word(s) that best completes each statement.
  - a. Advantages of open-center systems
    - 1) Less wear on pump parts because of continuous \_\_\_\_\_, but not continuous \_\_\_\_\_.
    - 2) No \_\_\_\_\_ pressure on hoses, steel lines, and connectors
  - b. Disadvantages of open-center systems
    - 1) Systems are not responsive to demands for \_\_\_\_\_ pressure
    - 2) Units such as \_\_\_\_\_ and \_\_\_\_\_ are not as responsive as in closed-center systems
  - c. Advantages of closed-center systems
    - 1) All components are more \_\_\_\_\_ than with open-center systems
    - 2) Systems can facilitate more \_\_\_\_\_ valves that can be operated simultaneously
  - d. Disadvantages of closed-center systems
    - 1) \_\_\_\_\_ pump wear
    - 2) Constant system pressure subjects components to \_\_\_\_\_

## TEST

5. Select true statements concerning fluid flow in an open-center circuit by placing an "X" in the appropriate blanks.
  - \_\_\_\_\_a. There is constant flow from reservoir to the pump to the rest of the system
  - \_\_\_\_\_b. When fluid flows to the control valve, if the valve is in neutral position, then the fluid is returned to the reservoir
  - \_\_\_\_\_c. When fluid flows to the control valve, if the valve is shifted, then the fluid is diverted to the pump
  - \_\_\_\_\_d. If the pressure of the system exceeds the setting of the relief valve a portion of the flow from the pump will be diverted back to the reservoir
  
6. Select true statements concerning fluid flow in multiple actuator open-center systems by placing an "X" in the appropriate blanks.
  - \_\_\_\_\_a. In the series connection, when one valve is shifted the fluid is diverted to the reservoir
  - \_\_\_\_\_b. The series-parallel connection is similar to the series connection, except when a valve is shifted the open-center neutral is opened
  - \_\_\_\_\_c. In the series connection configuration, the first valve has priority over the next valve, etc.
  - \_\_\_\_\_d. In the series parallel connection, if two actuators require approximately the same pressure then both will be operated
  
7. Distinguish between valves in the neutral and shifted positions in the fluid flow in a closed-center system by placing an "N" next to descriptions of valves in the neutral position and an "S" next to descriptions of valves in the shifted position.
  - \_\_\_\_\_a. The pressure builds up at the outlet until the compensator pressure is reached and the pump "destrokes" and no fluid is pumped from the pump
  - \_\_\_\_\_b. The pressurized fluid is directed to the actuators, which causes a drop in the pump outlet pressure
  - \_\_\_\_\_c. The drop in compensator pressure causes the pump to "stroke" and increase the displacement until adequate flow is available to satisfy the demands of all actuators
  - \_\_\_\_\_d. There is no flow path from the outlet of the pressure-compensated pump to the reservoir

## TEST

8. Identify the symbols used in a hydraulic schematic.



a. \_\_\_\_\_



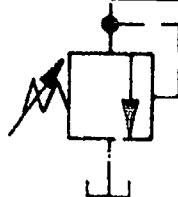
b. \_\_\_\_\_



c. \_\_\_\_\_



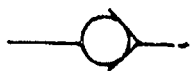
d. \_\_\_\_\_



e. \_\_\_\_\_



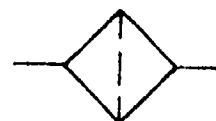
f. \_\_\_\_\_



g. \_\_\_\_\_



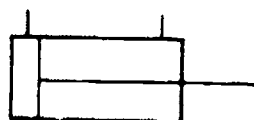
h. \_\_\_\_\_



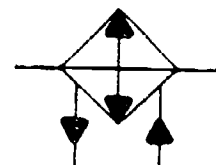
i. \_\_\_\_\_



j. \_\_\_\_\_



k. \_\_\_\_\_



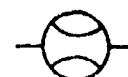
l. \_\_\_\_\_



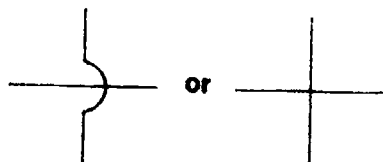
m. \_\_\_\_\_



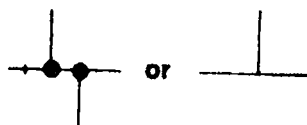
n. \_\_\_\_\_



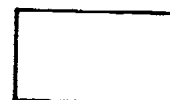
o. \_\_\_\_\_



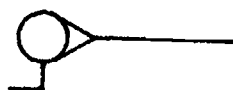
p. \_\_\_\_\_



q. \_\_\_\_\_



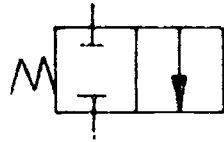
r. \_\_\_\_\_



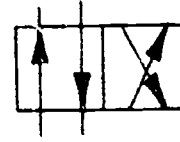
s. \_\_\_\_\_

# TEST

9. Identify the symbols for the various directional control valves.



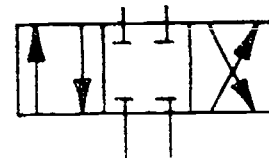
a. \_\_\_\_\_



b. \_\_\_\_\_



c. \_\_\_\_\_



d. \_\_\_\_\_

10. Draw a schematic of an open-center and a closed-center system.

a. Open-center

**TEST**

- b. Closed-center

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

- 11. Draw an open-center hydraulic circuit.
- 12. Show the oil flow in a circuit.



# HYDRAULIC CIRCUITS, DIAGRAMS, AND SYMBOLS

## UNIT XII

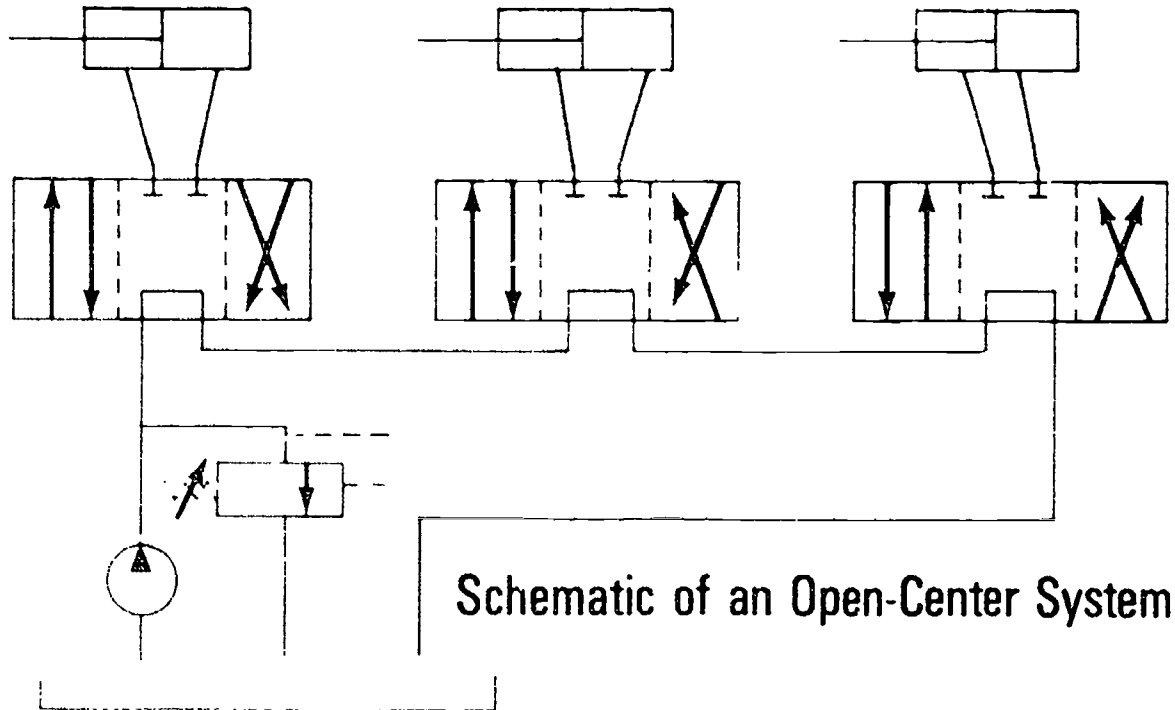
### ANSWERS TO TEST

1.   a.    7                   e.    9                   i.    5  
      b.    8                   f.    4  
      c.    1                  g.    6  
      d.    3                  h.    2
  
2.   a.    Reservoir  
      b.    Pump  
      c.    Control valve  
      d.    Cylinder (actuator)  
      e.    Lines
  
3.   a.    C                  d.    C  
      b.    C                  e.    O  
      c.    O
  
4.   a.    1)   Flow, pressure  
          2)   Constant  
      b.    1)   Immediate  
          2)   Brakes, steering  
      c.    1)   Responsive  
          2)   Remote  
      d.    1)   Excessive  
          2)   Stress
  
5.   a. b. c
  
6.   c. d
  
7.   a.    N  
      b.    S  
      c.    S  
      d.    N
  
8.   a.    Fixed displacement pump  
      b.    Variable displacement pump  
      c.    Pressure compensated pump  
      d.    Directional control valve  
      e.    Pressure relief valve  
      f.    Flow control valve  
      g.    Check valve  
      h.    Vented reservoir  
      i.    Filter  
      j.    Motor  
      k.    Cylinder  
      l.    Heat exchanger  
      m.    Pressure gauge  
      n.    Temperature gauge  
      o.    Flowmeter  
      p.    Lines, not joined  
      q.    Joining lines  
      r.    Pressurized reservoir  
      s.    Pilot operated check valve

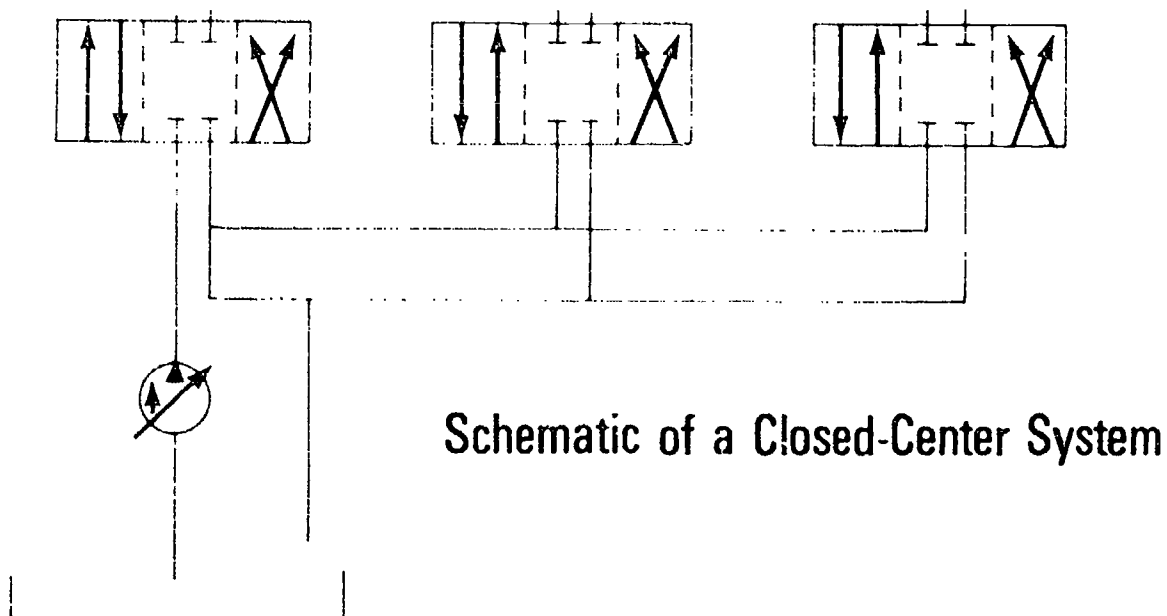
## ANSWERS TO TEST

9. a. Two-way, two position valve  
 b. Four-way, two position valve  
 c. Four-way, three position, open-center valve  
 d. Four-way, three position, closed-center valve

10. a.



b.



11. Evaluated to the satisfaction of the instructor  
 12. Evaluated to the satisfaction of the instructor

## **GENERAL MAINTENANCE**

### **UNIT XIII**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to list steps in keeping the hydraulic system clean and steps to be performed for general maintenance on a hydraulic system. The student should also be able to perform general maintenance procedures on a hydraulic system and change hydraulic fluid and filter. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Name three reasons for performing preventive maintenance.
2. List four factors that can damage a hydraulic system.
3. Select key maintenance problems.
4. List steps in keeping the hydraulic system clean.
5. List steps to be performed for general maintenance of a hydraulic system.
6. Demonstrate the ability to:
  - a. Perform general maintenance procedures on a hydraulic system. (Job Sheet #1)
  - b. Change hydraulic fluid and filter. (Job Sheet #2)

## **GENERAL MAINTENANCE UNIT XIII**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Discuss unit and specific objectives.
- D. Discuss information sheet.
- E. Demonstrate and discuss the procedures outlined in the job sheets.
- F. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Job sheets
  - 1. Job Sheet #1 — Perform General Maintenance Procedures on a Hydraulic System
  - 2. Job Sheet #2 — Change Hydraulic Fluid and Filter
- D. Test
- E. Answers to test

### **REFERENCES USED IN DEVELOPING THIS UNIT**

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1967.
- B. *Hydraulics*. Athens, GA 30602: American Association for Vocational Instructional Materials, 1974.

## **GENERAL MAINTENANCE UNIT XIII**

### **INFORMATION SHEET**

**I. Reasons for performing preventive maintenance**

- A. Prolong the life of the system
- B. Reduce down-time
- C. Reduce or eliminate needless failures

**II. Factors that can damage a hydraulic system**

- A. Too much speed
- B. Too much heat
- C. Too much pressure
- D. Too much contamination

**III. Key maintenance problems**

- A. Not enough oil in the reservoir
- B. Clogged or dirty oil filters
- C. Loose inlet lines
- D. Incorrect oil in the system

**IV. Steps in keeping the hydraulic system clean**

- A. Keep the oil clean
- B. Keep the system clean
- C. Keep the work area clean
- D. When changing or adding oil, be sure to use oil recommended by the manufacturer

**V. Steps to be performed for general maintenance of a hydraulic system**

- A. Check fluid level
- B. Inspect for leaks

## INFORMATION SHEET

- C. Inspect hoses, lines, and drive components for excessive wear
- D. Check for proper system operation
- E. During operation, watch and listen to system to check for:
  - 1. Unusual sounds
  - 2. Abnormal flow through the relief valve  
(NOTE: This is often indicated by a high-pitched sound.)
  - 3. Cavitation  
(NOTE: This is often indicated by a low-pitched sound.)
- F. Change filter and fluid according to manufacturer's recommendations

## GENERAL MAINTENANCE UNIT XIII

### JOB SHEET #1 — PERFORM GENERAL MAINTENANCE PROCEDURES ON A HYDRAULIC SYSTEM

**A. Tools and materials**

1. Clean lint-free shop towel
2. Hydraulic fluid as specified by manufacturer

**B. Procedure**

1. Clean filter cap and remove
2. Visually check fluid level

(NOTE: Level should be according to manufacturer's specifications.)

3. If the fluid level is low, add clean fluid to the reservoir

(NOTE: The fluid must be according to manufacturer's specifications.)

4. Visually inspect the system

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Check for frayed hoses and protect or cover hoses that are showing signs of wear		
b. Check for damaged lines		
c. Check drive line couplings to insure they are not excessively worn		
d. Check couplings to insure they are securely attached to the shafts		

5. Replace hoses, lines, and couplings that are damaged or excessively worn and report the problem to the instructor

**JOB SHEET #1**

6. Check the system for leaks and tighten any fitting which is leaking  
(NOTE: If this does not stop the leak, the fitting may have to be replaced.)
7. Start the system
8. Check the operation of all the functions of the system
9. Report any improper operation or any part that fails to function properly to the instructor
10. With the system operating, listen for unusual sounds, such as cavitation or improper operation of the relief valve
11. Change the filter and fluid according to manufacturer's specification  
(NOTE: This operation will be discussed in Job Sheet #2.)
- ☐ Have you instructor check your work
12. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor



## **GENERAL MAINTENANCE UNIT XIII**

### **JOB SHEET #2 — CHANGE HYDRAULIC FLUID AND FILTER**

#### **A. Tools and materials**

1. Wrench to fit reservoir drain plug
2. Wrench for removing filter
3. Clean lint-free shop towels
4. Hydraulic fluid according to manufacturer's recommendations
5. Hydraulic filter

#### **B. Procedure**

1. Operate levers to release system pressure
2. Slowly open reservoir filler cap to relieve pressure on reservoir
3. Drain the fluid by removing the drain plug in the reservoir
4. Open the inspection plate on the reservoir
5. Remove any dirt and foreign material which has settled in the bottom of the reservoir
6. Replace the inspection plate and drain plug
7. Clean the area around the filter
8. Remove the old filter
9. Clean the filter housing if it is a cartridge type filter
10. Install a new filter and tighten to manufacturer's specifications
11. Fill the reservoir with hydraulic fluid
12. Bleed system if necessary
13. Operate system and check for leaks
14. Check fluid level to insure it is still within specifications

**JOB SHEET #2**

15. Remove and clean the inlet screen

☐ Have your instructor check your work

16. Clean up area and return tools and materials to proper storage

## GENERAL MAINTENANCE UNIT XIII

NAME \_\_\_\_\_

### TEST

1. Name three reasons for performing preventive maintenance.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
2. List four factors that can damage a hydraulic system.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
  - d. \_\_\_\_\_
3. Select key maintenance problems by placing an "X" in the appropriate blanks.
  - \_\_\_\_\_a. Too much oil in the reservoir
  - \_\_\_\_\_b. Clogged or dirty oil filters
  - \_\_\_\_\_c. Tight inlet lines
  - \_\_\_\_\_d. Incorrect oil in the system
4. List three steps in keeping the hydraulic system clean.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
5. List five steps to be performed for general maintenance of a hydraulic system.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
  - d. \_\_\_\_\_
  - e. \_\_\_\_\_

## TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

6. Demonstrate the ability to:
  - a. Perform general maintenance procedures on a hydraulic system.
  - b. Change hydraulic fluid and filter.

## GENERAL MAINTENANCE UNIT XIII

### ANSWERS TO TEST

1.
  - a. Prolong the life of the system
  - b. Reduce the down-time
  - c. Reduce or eliminate needless failures
2.
  - a. Too much speed
  - b. Too much heat
  - c. Too much pressure
  - d. Too much contamination
3.
  - b, d
4. Any three of the following:
  - a. Keep the oil clean
  - b. Keep the system clean
  - c. Keep the work area clean
  - d. When changing or adding oil, be sure to use oil recommended by the manufacturer
5. Any five of the following:
  - a. Check fluid level
  - b. Inspect for leaks
  - c. Inspect hoses, lines, and drive components for excessive wear
  - d. Check for proper system operation
  - e. During operation, watch and listen to system to check for:
    - 1) Unusual sounds
    - 2) Abnormal flow through the relief valve
    - 3) Cavitation
  - f. Change filter and fluid according to manufacturer's recommendations
6. Performance skills evaluated to the satisfaction of the instructor

## **DIAGNOSIS AND TESTING**

### **UNIT XIV**

#### **UNIT OBJECTIVE**

After completion of this unit, the student should be able to discuss steps in troubleshooting and how to use hydraulic system testers. The student should also be able to list problems and remedies for such system malfunctions as running too fast, running too slow, operating erratically, and overheating. The student should also be able to use test equipment to locate a problem in a system and test a hydraulic pump. This knowledge will be evidenced by correctly performing the procedures outlined in the job sheets and by scoring 85 percent on the unit test.

#### **SPECIFIC OBJECTIVES**

After completion of this unit, the student should be able to:

1. Define terms associated with diagnosis and testing.
2. Arrange in order the steps in troubleshooting.
3. Identify the types of hydraulic system testers.
4. Match problems with remedies for inoperative systems..
5. List remedies for problems with systems that operate erratically.
6. Match problems with remedies for systems that operate slowly.
7. Discuss two problems and remedies for systems that operate too fast.
8. Match problems with remedies for systems that overheat.
9. List problems and remedies for foaming fluid.
10. Match problems with remedies for excessive pump noise.
11. List two problems and remedies for leaking pumps.
12. Match problems with remedies for load drop when the control valve is in the neutral position.
13. List problems which can cause the control valve to stick or work hard.

## OBJECTIVE SHEET

14. Select problems which can cause a control valve to leak.
15. List problems which can cause a cylinder to leak.
16. List three problems which can cause a cylinder to actually lower when a control valve is moved to slowly raise a cylinder.
17. Match problems with remedies for power steering malfunctions.
18. Match problems with remedies for brake malfunctions.
19. Demonstrate the ability to:
  - a. Test a hydraulic pump. (Job Sheet #1)
  - b. Locate a problem in a hydraulic system. (Job Sheet #2)
  - c. Test a relief valve. (Job Sheet #3)
  - d. Test a control valve. (Job Sheet #4)
  - e. Test an actuator. (Job Sheet #5)

## **DIAGNOSIS AND TESTING UNIT XIV**

### **SUGGESTED ACTIVITIES**

- A. Provide students with objective sheet.
- B. Provide students with information and job sheets.
- C. Make transparency.
- D. Discuss unit and specific objectives.
- E. Discuss information sheet.
- F. Demonstrate and discuss the procedures outlined in the job sheets.
- G. Give test.

### **CONTENTS OF THIS UNIT**

- A. Objective sheet
- B. Information sheet
- C. Transparency Master 1 — Hydraulic System Testers
- D. Job sheets
  - 1. Job Sheet #1 — Test a Hydraulic Pump
  - 2. Job Sheet #2 — Locate a Problem in a Hydraulic System
  - 3. Job Sheet #3 — Test a Relief Valve
  - 4. Job Sheet #4 — Test a Control Valve
  - 5. Job Sheet #5 — Test an Actuator
- E. Test
- F. Answers to test

### **REFERENCES USED IN DEVELOPING THIS UNIT**

- A. *Fundamentals of Service, Hydraulics*. Moline, IL: Deere and Company, 1967.
- B. *Hydraulics*. Athens, GA 30602: American Association for Vocational Instructional Materials, 1974.



## **DIAGNOSIS AND TESTING UNIT XIV**

### **INFORMATION SHEET**

#### **I. Terms and definitions**

- A. Troubleshooting — The systematic diagnosis of hydraulic system malfunctions
- B. Diagnosis — A statement or conclusion concerning the nature or cause of a problem
- C. Hydraulic system tester — A device which is capable of measuring hydraulic system pressure flow and temperature and also has a valve for imposing a load onto the system

#### **II. Steps in troubleshooting**

- A. Know the system

(NOTE: Study technical manuals and how the system works to familiarize yourself with the operation of the circuit.)

- B. Discuss the problems with the operator

(NOTE: Ask operator what warning signs preceded the trouble, what previous work has been done on the system, and if similar trouble occurred before. This is frequently the most valuable troubleshooting tool of all.)

- C. Operate the machine

- D. Inspect the machine

(NOTE: Make a close inspection for unusual noises and smells. Look for damaged lines and evidence of excessive temperature.)

- E. List the possible causes

- F. Reach a conclusion

- G. Test your conclusion

#### **III. Types of hydraulic system testers (Transparency 1)**

- A. By-pass tester

- B. In-line tester

## INFORMATION SHEET

### IV. Problems and remedies for inoperative systems

- A. No oil in system
  - 1. Fill to full mark
  - 2. Check system for leaks
- B. Oil low in reservoir
  - 1. Check level and fill to full mark
  - 2. Check system for leaks
- C. Oil of wrong viscosity — Refer to specifications for proper viscosity
- D. Filter dirty or plugged
  - 1. Drain oil
  - 2. Clean suction screen
  - 3. Try to find source of contamination
  - 4. Replace filter
- E. Restriction in system
  - 1. Oil lines could be dirty or have inner walls that are collapsing to cut off oil supply
  - 2. Clean or replace lines
  - 3. Clean orifices
- F. Air leaks in pump suction line — Repair or replace lines
- G. Dirt in pump
  - 1. Clean and repair pump
  - 2. If necessary, drain and flush hydraulic system
  - 3. Try to find source of contamination
- H. Badly worn pump
  - 1. Repair or replace pump
  - 2. Check for problems causing pump wear such as misalignment or contaminated oil

## INFORMATION SHEET

- I. **Badly worn components** — Examine and test valves, motors, cylinders, etc. for external and internal leaks

(NOTE: If wear is abnormal, try to locate the cause.)

- J. **Oil leak in pressure lines**

1. Tighten fittings or replace defective lines
2. Examine mating surfaces on couplers for irregularities

- K. **Components not properly adjusted** — Refer to machine technical manual for proper adjustment of components

- L. **Relief valve defective**

1. Test relief valves to make sure they are opening at their rated pressure
2. Examine seals for damage that could cause leaks
3. Clean relief valves and check for broken springs, etc.

- M. **Pump rotating in wrong direction** — Reverse to prevent damage

- N. **Operating system under excessive load** — Check specifications of unit for load limits

- O. **Hoses attached improperly** — Attach properly and tighten securely

- P. **Slipping or broken pump drive**

1. Replace couplers or belts if necessary
2. Align them and adjust tension

- Q. **Pump not operating** — Check for shut-off device on pump or pump drive

**V. Problems and remedies for systems that operate erratically**

- A. **Air in system**

1. Examine suction side of system for leaks
2. Make sure oil level is correct

(NOTE: Oil leak on the pressure side of the system could account for loss of oil.)

## INFORMATION SHEET

- B. Cold oil
  - 1. Viscosity of oil may be too high at start of warm-up period
  - 2. Allow oil to warm up to operating temperature before using hydraulic functions
- C. Components sticking or binding
  - 1. Check for dirt or gummy deposits, and if dirt is caused by contamination, try to find the source
  - 2. Check for worn or bent parts
- D. Pump damaged — Check for broken or worn parts and determine cause of pump damage
- E. Dirt in relief valves — Clean relief valves
- F. Restriction in filter or suction line
  - 1. Suction line could be dirty or have inner walls that are collapsing to cut off oil supply
  - 2. Clean or replace suction line
  - 3. Check filter line for restrictions
- G. Hydraulic cylinder leaking internally — Repair or replace cylinder packing

### VI. Problems and remedies for systems that operate slowly

- A. Cold oil — Allow oil to warm up before operating machine
- B. Oil viscosity too heavy — Use oil recommended by the manufacturer
- C. Insufficient engine speed
  - 1. Refer to operator's manual for recommended speed
  - 2. If machine has a governor, it may need adjustment
- D. Low oil supply
  - 1. Check reservoir and add oil if necessary
  - 2. Check system for leaks that could cause loss of oil
- E. Adjustable orifice restricted too much
  - 1. Back out orifice and adjust it
  - 2. Check machine specifications for proper setting

## INFORMATION SHEET

- F. Air in system — Check suction side of the system for leaks
- G. Badly worn pump
  - 1. Repair or replace pump
  - 2. Check for problems causing pump wear such as misalignment or contaminated oil
- H. Restriction in suction line or filter
  - 1. Suction line could be dirty or have inner walls that are collapsing to cut off oil supply
  - 2. Clean or replace suction line
  - 3. Examine filter for plugging
- I. Relief valves not properly set or leaking
  - 1. Test relief valves to make sure they are opening at their rated pressure
  - 2. Examine valves for damaged seats that could leak
- J. Badly worn components
  - 1. Examine and test valves, motors, cylinders, etc. for external and internal leaks
  - 2. If wear is abnormal, try to locate the cause
- K. Valve or regulators plugged
  - 1. Clean dirt from components
  - 2. Clean orifices
  - 3. Check source of dirt and correct
- L. Oil leak in pressure lines
  - 1. Tighten fittings or replace defective lines
  - 2. Examine mating surfaces on couplers for irregularities
- M. Components not properly adjusted — Refer to machine technical manual for proper adjustment of components

## INFORMATION SHEET

### VII. Problems and remedies for systems that operate too fast

- A. Adjustable orifice installed backward or not installed — Install orifice parts correctly and adjust
- B. Obstruction or dirt under seat of orifice — Remove foreign material and readjust orifice
- C. Pressure set too high (could cause damage) — Readjust pressure to manufacturer's specifications

### VIII. Problems and remedies for systems that overheat

- A. Operator holds control valves in power position too long, causing relief valve to open — Return control of lever to neutral position when not in use
- B. Using incorrect oil
  - 1. Use oil recommended by manufacturer
  - 2. Be sure oil viscosity is correct
- C. Low oil level
  - 1. Fill reservoir
  - 2. Look for leaks
- D. Dirty oil
  - 1. Drain and refill with clean oil
  - 2. Look for source of contamination
- E. Engine running too fast — Reset governor or reduce throttle
- F. Incorrect relief valve pressure — Check pressure and clean or replace relief valves
- G. Internal component oil leakage — Examine and test valves, cylinders, motors, etc. for external and internal leaks
  - (If oil leakage is abnormal, try to locate cause.)
- H. Restriction in pump suction line — Clean or replace
- I. Dented, obstructed, or undersized oil lines
  - 1. Replace defective or undersized oil lines
  - 2. remove obstructions

## INFORMATION SHEET

- J. Oil cooler malfunctioning — Clean or repair
- K. Control valve stuck in partially or full open position — Free all spools so that they return to neutral position
- L. Heat not radiating properly — Clean dirt and mud from reservoir, oil lines, coolers, and other components
- M. Automatic unloading control inoperative (if equipped) — Repair valve

### IX. Problems and remedies for foaming fluid

- A. Low fluid level — Fill reservoir and look for leaks
- B. Water in fluid — Drain and replace fluid
- C. Wrong kind of fluid being used — Use fluid recommended by manufacturer
- D. Air leak in line from reservoir to pump — Tighten or replace suction line
- E. Kink or dent in fluid lines (restricts fluid flow) — Replace fluid lines
- F. Worn seal around pump shaft — Clean sealing area, replace seal, and check fluid for contamination or pump for misalignment

### X. Problems and remedies for excessive pump noise

- A. Low fluid level
  - 1. Fill reservoir
  - 2. Check system for leaks
- B. Fluid viscosity too high — Change fluid to correct viscosity
- C. Pump speed too fast — Operate pump at recommended speed
- D. Suction line plugged or pinched — Clean or replace line between reservoir and pump
- E. Sludge and dirt in pump
  - 1. Disassemble and inspect pump and lines
  - 2. Clean hydraulic system
  - 3. Determine cause of dirt

## INFORMATION SHEET

- F. Reservoir air vent plugged — Remove breather cap, flush, and clean air vent
  - G. Air in fluid
    - 1. Tighten or replace suction line
    - 2. Check system for leaks
    - 3. Replace pump shaft seal
  - H. Worn or scored pump bearings or shafts
    - 1. Replace worn parts or complete pump if parts are badly worn or scored
    - 2. Determine cause of scoring
  - I. Inlet screen plugged — Clean screen to prevent cavitation in the pump
  - J. Broken or damaged pump parts
    - 1. Repair pump
    - 2. Look for cause of damage like contamination or too much pressure
  - K. Sticking or binding parts
    - 1. Repair binding parts
    - 2. Clean parts and change fluid if necessary
- XI. Problems and remedies for leaking pumps**
- A. Damaged seal around drive shaft — Tighten packing or replace seal
 

(NOTE: Trouble may be caused by contaminated oil. Check oil for abrasives and clean entire hydraulic system. Try to locate source of contamination. Check the pump drive shaft. Misalignment could cause the seal to wear. If shaft is not aligned, check the pump for other damage.)
  - B. Loose or broken pump parts — Tighten or replace parts
 

(NOTE: Make sure all bolts and fittings are tight. Check gaskets. Examine pump castings for cracks. If pump is cracked, look for a cause like too much pressure or hoses that are attached incorrectly.)



## INFORMATION SHEET

- XII. Problems and remedies for load drop when the control valve is in the neutral position**
- A. Leaking or broken oil lines from control valve to cylinder
    - 1. Check for leaks
    - 2. Tighten or replace lines
    - 3. Examine mating surfaces on couplers or irregularities
  - B. Oil leaking past cylinder packings or O-rings
    - 1. Replace worn parts
    - 2. If wear is caused by contamination, clean hydraulic system and determine the source
  - C. Oil leaking past control valve or relief valves
    - 1. Clean or replace valves
    - 2. Wear may be caused by contamination
    - 3. Clean system and determine source of contamination
  - D. Control lever not centering when released
    - 1. Check linkage for binding
    - 2. Make sure valve is properly adjusted and has no broken or binding parts such as spools or detent springs
- XIII. Problems which can cause the control valve to stick or work hard**
- A. Misalignment or seizing of control linkage
  - B. Tie bolts too tight (on valve stacks)
  - C. Valve broken or scored internally
- XIV. Problems which can cause a control valve to leak**
- A. Tie bolts too loose (on valve stacks)
  - B. Worn or damaged O-rings
  - C. Broken valve parts
  - D. Excessive wear between a select-fit spool and valve

## INFORMATION SHEET

### **XV. Problems which can cause a cylinder to leak**

- A. Damaged cylinder barrel
- B. Rod seal leaking

(NOTE: If contamination has caused seal to wear, look for source. Wear may be caused by external as well as internal contaminants. Check piston rod for scratches or misalignment.)

- C. Loose parts
- D. Piston rod damaged

### **XVI. Problems which can cause a cylinder to actually lower when control valve is moved to slowly raise a cylinder**

- A. Damaged check valve in lift circuit
- B. Leaking cylinder packing
- C. Leaking lines or fittings to cylinder
- D. Detent springs need adjustment

### **XVII. Problems and remedies for power steering malfunctions**

- A. Air in system
  - 1. Bleed system
  - 2. Check for air leaks
- B. Internal leakage in system
  - 1. Components may not be adjusted properly
  - 2. Parts may be worn or broken
  - 3. Check for cause of wear
- C. System not properly timed — Time according to manufacturer's instructions
- D. Worn or damaged bearings — Check and replace bearings in steering components

## INFORMATION SHEET

E. Insufficient pressure

1. Check pump and relief valves
2. Contamination could cause valves to leak or pump to wear
3. Restricted filters

**XVIII. Problems and remedies for brake malfunctions**

A. Heavy oil or improper brake fluid

1. Warm up fluid or change to one of lighter viscosity
2. Use proper oil or brake fluid (see machine operator's manual)

**(CAUTION:** Many brake circuits use brake fluid instead of hydraulic oil. DO NOT MIX.)

B. Air in system

1. Bleed brake system
2. Find out where air is coming from

C. Contaminated oil — Clean and repair system and check for cause of contamination

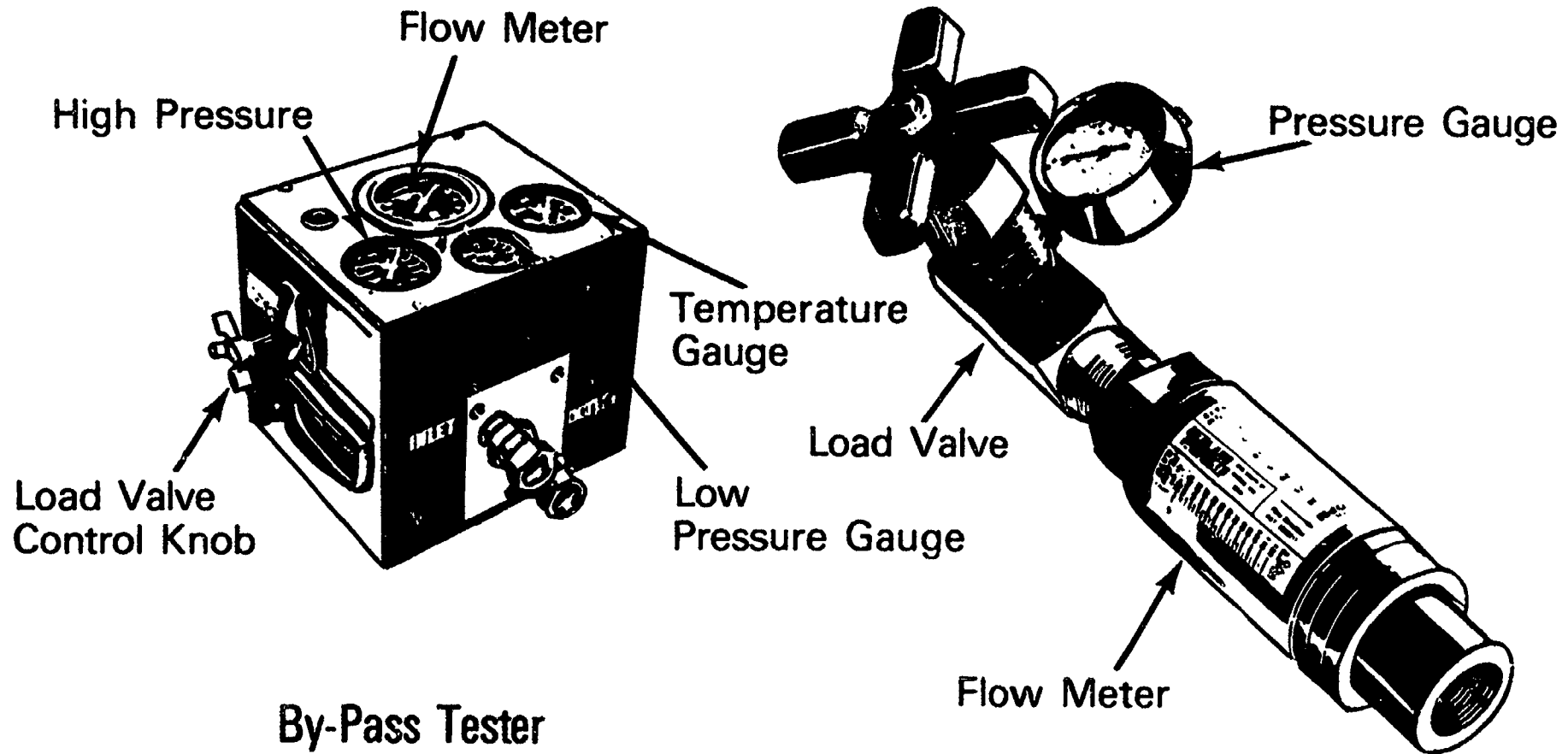
D. Brake pedal return restricted

1. Clean dirt from moving parts
2. Check linkage for damage
3. Brake pistons may be leaking

E. Accumulator not working (if equipped)

1. Check accumulator precharge
2. If accumulator is defective, repair or replace it

# Hydraulic System Testers



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In-Line Tester

344

## DIAGNOSIS AND TESTING UNIT XIV

### JOB SHEET #1 — TEST A HYDRAULIC PUMP

A. Tools and materials

1. Open-center hydraulic system
2. Hydraulic system tester
3. Hand tools
4. Service manual for hydraulic system
5. Safety glasses

B. Procedure

(NOTE: The performance of a fixed displacement pump is to be tested using a hydraulic system tester.)

1. Disconnect the line connected to the pump outlet
2. Connect the pump outlet to the inlet of the tester, connect the tester outlet to the reservoir, and make sure line is secure into reservoir
3. Open the load valve completely  
(CAUTION: Important! Failure to do this could cause serious damage or injury.)
4. Start pump and check for leaks
5. Close the load valve slowly so that the pump outlet is approximately 500 PSI, and let the system operate at this pressure until it has reached operating temperature
6. Open the load valve and record the no-load flow
7. Close the load valve slowly until the pump outlet pressure has reached 250 PSI and record the flow rate at this pressure
8. Close the load valve slowly and record the flow rate out of the pump in 250 PSI increments until maximum system pressure is reached, then record reading in Table 1
9. Note that the pump is faulty if it fails to supply 70% of the no-load flow at full load; the pump is also faulty if it fails to supply adequate no-load flow

(NOTE: Refer to service manual for proper no-load flow.)

# **JOB SHEET #1**

10. Stop engine, remove tester, and reconnect the pump outlet line

Outlet Pressure (PSI)	Outlet Flow Rate (GPM)
250	
500	
750	
1000	
1250	
1500	
1750	
2000*	
2250*	
2500*	
2750*	
3000*	

(CAUTION: Do not exceed rated pressure for system.)

$$\text{Flow ratio} = \frac{\text{Full load flow rate}}{\text{No-load flow rate}} = \underline{\hspace{2cm}}$$

Table 1      Pump Test Data

- ☐ Have your instructor check your work

11. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor.

## DIAGNOSIS AND TESTING UNIT XIV

### JOB SHEET #2 — LOCATE A PROBLEM IN A HYDRAULIC SYSTEM

**A. Tools and materials**

1. Hydraulic system with a known defect
2. Service manual
3. Hand tools
4. Safety glasses

**B. Procedures**

(NOTE: The seven basic steps for diagnosing a system are to be followed.)

1. Review the service manual so that you will know the system
2. Discuss the symptoms with the operator or the person reporting the problem
3. Check fluid levels
4. Operate the machine

(NOTE: Make sure no one is in the way.)

- a. Operate it until it has warmed up and observe the problem yourself
- b. Note any unusual sounds or smells
- c. Note sluggish or erratic behavior
5. Inspect the machine

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
a. Look for leaks and damaged lines		
b. Check the reservoir for low or oil foaming		
c. Does it look milky? Does the oil smell scorched?		

6. List possible causes
7. Reach a conclusion — Decide on the most likely cause of the problem based on the symptoms previously observed

**JOB SHEET #2**

8. Test your solution

(NOTE: Do this by reporting your findings to your instructor.)

☐

Have your instructor check your work

9. Clean up area and return tools and materials to proper storages, or prepare for next job sheet as directed by your instructor



# DIAGNOSIS AND TESTING UNIT XIV

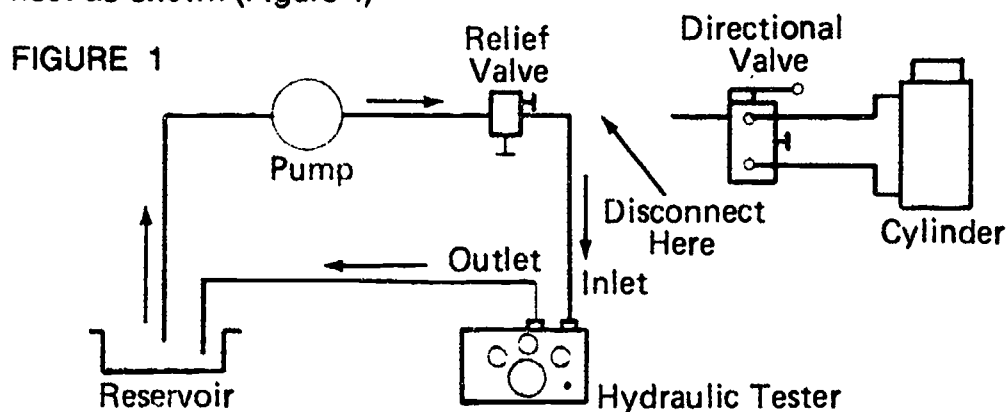
## JOB SHEET #3 — TEST A RELIEF VALVE

### A. Tools and materials

1. Open-center hydraulic system
2. Hydraulic system tester
3. Hand tools
4. Service manual for hydraulic system
5. Operator's manual for tester
6. Safety glasses
7. Lint-free rope

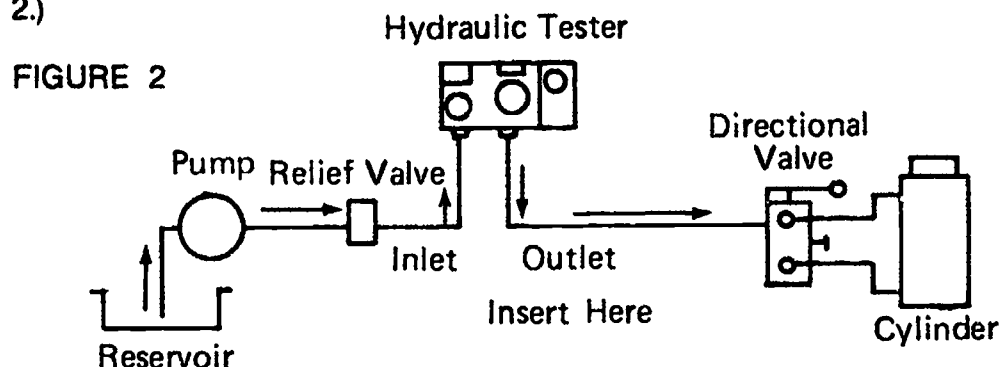
### B. Procedure

1. Verify that pump is functioning properly
2. If using a bypass tester disconnect the pump outlet past the relief valve and connect as shown (Figure 1)



3. Connect the outlet of the test back to the reservoir and secure this line with line-free rope

(NOTE: If using an in-line tester connect in series after the relief valve. See Figure 2.)



**JOB SHEET #3**

4. Make sure the load valve is in the no-load position
5. Start hydraulic system drive and operate at rated speed
6. Operate system until fluid reaches rated temperature
7. Close the load valve slowly until the flow measured on the tester reached 0 or the pressure exceeds the maximum allowable amount
  - a. If the flow is zero and the pressure is within 50 PSI of the rated setting then the relief is set to the correct value
  - b. Record relief pressure: \_\_\_\_\_ PSI
  - c. If the flow is zero and the pressure is less than 50 PSI below the rated setting then slowly adjust the relief valve to the specified value
  - d. Record actual setting: \_\_\_\_\_ PSI
  - e. Adjust the relief valve setting until the flow through the tester has been reduced
  - f. Slowly continue to close the load until the pressure reaches the maximum value
  - g. Repeat this process until the flow rate is zero and the pressure is within specification
  - h. Record actual setting \_\_\_\_\_ PSI
8. Open the load valve slowly until the pressure is 200 PSI for compound (or 500 for a simple) relief valve
9. Measure the flow rate

(NOTE: This should be the rated flow rate of the system. If this flow rate is low then the relief valve is leaking or is faulty.)
10. Record flow rate: \_\_\_\_\_ GPM
11. Open load valve
12. Shut drive off
13. Remove tester and reconnect lines
- ☐ Have your instructor check you work
14. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor

## DIAGNOSIS AND TESTING UNIT XIV

### JOB SHEET #4 — TEST A CONTROL VALVE

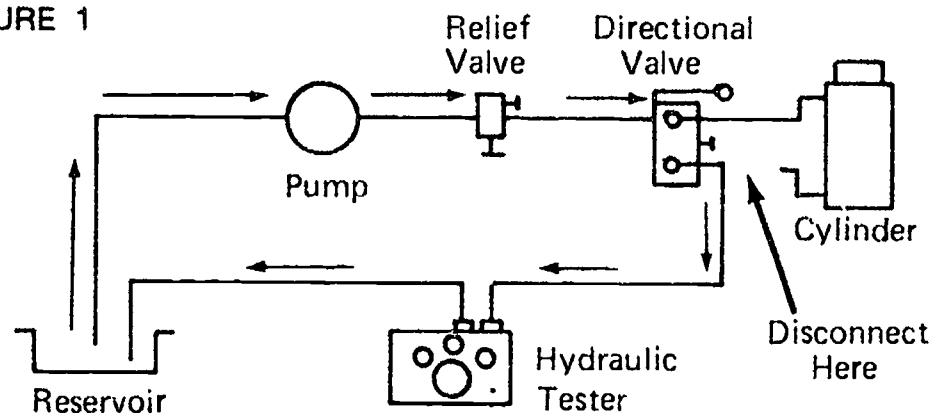
#### A. Tools and materials

1. Open-center hydraulic system
2. Bypass or inline hydraulic system tester
3. Hand tools
4. Service manual for tester
5. Operator's manual for tester
6. Lint-free rope
7. Safety glasses

#### B. Procedure

1. Verify that the pump and relief valve are functioning properly
2. Connect the tester to one of the outlet parts of the control valves similar to Figure 1

FIGURE 1



3. Connect to return line from the tester to the reservoir and secure with the lint-free rope
4. Make sure any buckets or attachments are firmly secured
5. Open the tester load valve
6. Start the pump drive and operate at rated speed

**JOB SHEET #4**

7. Operate the system until the fluid reaches operating temperature
8. Check to insure that buckets and attachment are firmly supported, then shift the valve to direct flow through the tester

(CAUTION: Failure to properly secure attachments can result in severe bodily injury.)

(NOTE: Do *NOT* shift the valve the other direction.)

9. With no load on the system (load valve completely open) measure the flow rate through the tester

(NOTE: This should be approximately the rated capacity of the pump.)

10. Record the flow rate: \_\_\_\_\_ GPM
11. Close the load valve slowly until the pressure is 100 PSI less than the relief valve pressure
12. Measure the flow rate at the above settings
13. Record flow rate \_\_\_\_\_ GPM

(NOTE: If the load flow rate measured above is close to the no-load flow rate previously measured then the valve is functioning properly. If a large drop occurs (more than 50 percent) then the valve is leaking and should be repaired.)

14. Record the observed condition: \_\_\_\_\_
15. Repeat this procedure for the other outlet part (if any)
16. Turn off drive
17. Disconnect the tester
18. Reconnect the lines
- ☐ Have your instructor check your work

19. Clean up area and return tools and materials to proper storage, or prepare for next job sheet as directed by your instructor

## DIAGNOSIS AND TESTING UNIT XIV

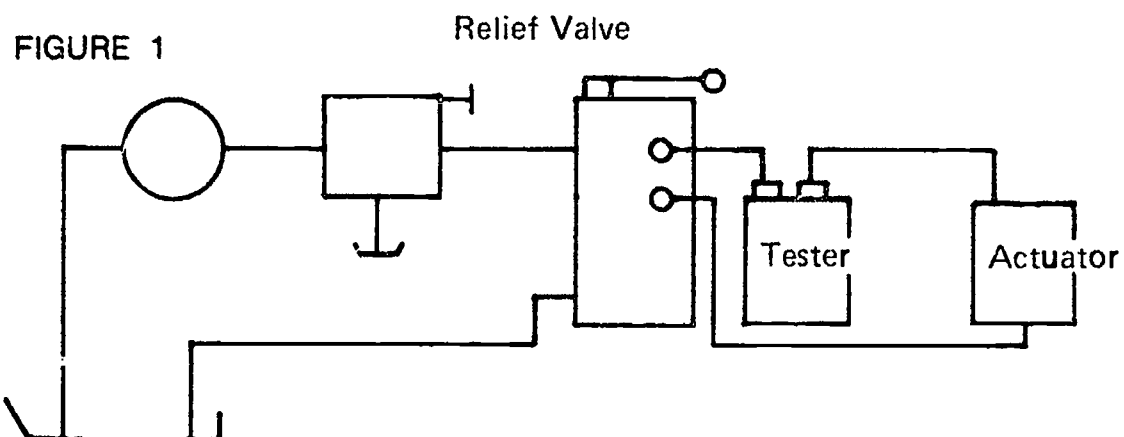
### JOB SHEET #5 — TEST AN ACTUATOR

#### A. Tools and materials

1. Hydraulic system with an actuator (cylinder or a motor)
2. Hand tools
3. Service manual for hydraulic system
4. In-line hydraulic system tester
5. Manual for tester
6. Safety glasses
7. Device for measuring the motor shaft speed

#### B. Procedure

1. Verify that the pump, relief valve, and control valve are functioning properly
2. Connect the in-line tester between the control valve and actuator as shown in Figure 1



3. Open the tester load valve
4. Start the pump drive and operate at rated speed
5. Operate the system until the fluid has reached operating temperature
6. Shift the control valve to direct flow to the actuator

**JOB SHEET #5**

7. If a cylinder is being tested then measure the pressure and flow when the cylinder is fully retracted and extended

Extended: Pressure \_\_\_\_\_ PSI  
Flow \_\_\_\_\_ GPM

Retracted: Pressure \_\_\_\_\_ PSI  
Flow \_\_\_\_\_ GPM

(NOTE: If any flow is measured then the cylinder is leaking internally and is defective and must be repaired. The pressure shows relief valve pressure in one direction and zero in the other direction. If this is not found to be correct then either the test configuration is not correct or some other component is faulty.)

8. Measure the shaft speed to the motor with no load, if a motor is being tested
9. Record the motor inlet pressure and the motor speed

(NOTE: The speed should be close to the theoretical value.)

No-load pressure: \_\_\_\_\_ PSI

No-load speed: \_\_\_\_\_ RPM

Theoretical flow: \_\_\_\_\_ RPM  
if known

10. Apply a load to the motor to obtain a motor inlet pressure which is 200 PSI less than the relief valve pressure
11. Measure the pressure and speed and record

(NOTE: The ratios of the full-load speed to the no load speed should be no less than 0.7. If it is less than this figure then the motor is defective and should be repaired.)

Full-load pressure: \_\_\_\_\_ PSI

Full-load flow rate: \_\_\_\_\_ RPM

Full-load speed : \_\_\_\_\_  
No-load speed

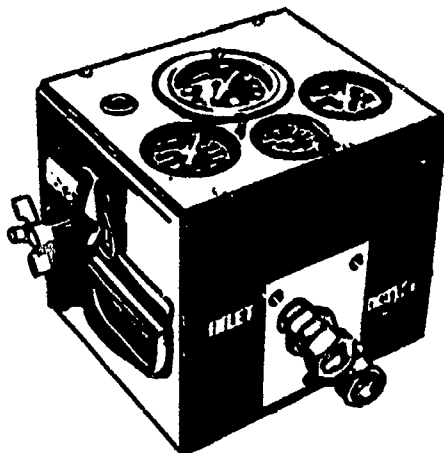
12. Turn off the pump drive
13. Disconnect tester
14. Reconnect lines
- ☐ Have your instructor check your work
15. Clean up area and return tools and materials to proper storage

## DIAGNOSIS AND TESTING UNIT XIV

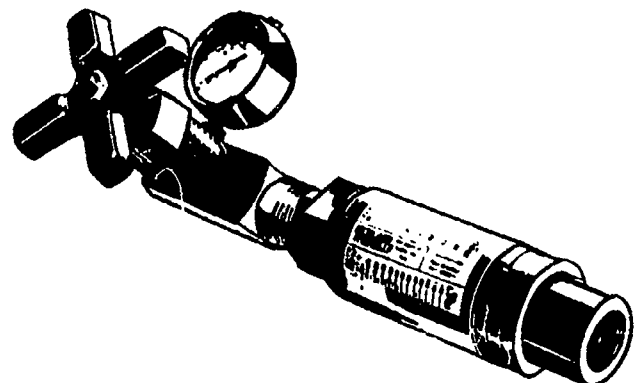
NAME \_\_\_\_\_

### TEST

1. Define the following terms associated with diagnosis and testing.
  - a. Troubleshooting — \_\_\_\_\_
  - b. Diagnosis — \_\_\_\_\_
  - c. Hydraulic system tester — \_\_\_\_\_
2. \_\_\_\_\_ in order the steps for troubleshooting by placing the correct sequence number in appropriate blanks.
  - \_\_\_\_\_ a. Operate the machine
  - \_\_\_\_\_ b. List the possible causes
  - \_\_\_\_\_ c. Reach a conclusion
  - \_\_\_\_\_ d. Discuss the problems with the operator
  - \_\_\_\_\_ e. Test your condition
  - \_\_\_\_\_ f. Inspect the machine
  - \_\_\_\_\_ g. Know the system
3. Identify the types of hydraulic system testers.



a. \_\_\_\_\_



b. \_\_\_\_\_

## TEST

### 4. Match the problems with remedies for inoperative systems

- |   |   |
|---|---|
| <p>_____a.     1) Fill to full mark<br/>              2) Check system for leaks</p>   | <p>1. Badly worn pump</p>                       |
| <p>_____b.     1) Check level and fill to full mark<br/>              2) Check system for leaks</p>   | <p>2. Components not properly adjusted</p>      |
| <p>_____c.     Refer to specifications for proper viscosity</p>   | <p>3. Pump rotating in wrong direction</p>      |
| <p>_____d.     1) Drain oil<br/>              2) Clean suction screen<br/>              3) Try to find source of contamination<br/>              4) Replace filter</p>  | <p>4. Oil of wrong viscosity</p>                |
| <p>_____e.     1) Oil lines could be dirty or have inner walls that are collapsing to cut off oil supply<br/>              2) Clean or replace lines<br/>              3) Clean orifices</p>  | <p>5. Hoses attached improperly</p>             |
| <p>_____f.     Repair or replace lines</p>  | <p>6. Air leaks in pump suction line</p>        |
| <p>_____g.     1) Clean and repair pump<br/>              2) If necessary, drain and flush hydraulic system<br/>              3) Try to find source of contamination</p>  | <p>7. No oil in system</p>                      |
| <p>_____h.     1) Repair or replace pump<br/>              2) Check for problems causing pump wear such as misalignment or contaminated oil</p>   | <p>8. Oil leak in pressure lines</p>            |
| <p>_____i.     Examine and test valves, motors, cylinders, etc., for external and internal leaks</p>  | <p>9. Operating system under excessive load</p> |
| <p>_____j.     1) Tighten fittings or replace defective lines<br/>              2) Examine mating surfaces on couplers for irregularities</p>   | <p>10. Restriction in system</p>                |
| <p>_____k.     Refer to machine technical manual for proper adjustment or components</p>  | <p>11. Dirt in pump</p>                         |
| <p>_____l.     1) Test relief valves to make sure they are opening at their rated pressure<br/>              2) Examine seals for damage that could cause leaks<br/>              3) Clean relief valves and check for broken springs, etc.</p> | <p>12. Slipping or broken pump drive</p>        |
|   | <p>13. Relief valve defective</p>               |
|   | <p>14. Oil low in reservoir</p>                 |
|   | <p>15. Badly worn components</p>                |
|   | <p>16. Pump not operating</p>                   |
|   | <p>17. Filter dirty or plugged</p>              |



## TEST

- \_\_\_\_\_m. Reverse to prevent damage
- \_\_\_\_\_n. Check specifications of unit for load limits
- \_\_\_\_\_o. Attch properly and tighten securely
- \_\_\_\_\_p. 1) Replace couplers or belts if necessary  
2) Align them and adjust tension
- \_\_\_\_\_q. Check for shut-off device on pump or pump drive
5. List one remedy for each of the following problems with systems that operate erratically.
- a. Air in system — \_\_\_\_\_
- b. Cold oil — \_\_\_\_\_
- c. Components sticking or binding — \_\_\_\_\_
- d. Pump damaged — \_\_\_\_\_
- e. Dirt in relief valves — \_\_\_\_\_
- f. Restriction in filter or suction line — \_\_\_\_\_
- g. Hydraulic cylinder leaking internally — \_\_\_\_\_
6. Match problems with remedies for systems that operate slowly.
- |   |  |
|---|--|
| _____a. Allow oil to warm up before operating machine   | 1. Low oil supply                            |
| _____b. Use oil recommended by the manufacturer   | 2. Air in system                             |
| _____c. 1) Refer to operator's manual for recommended speed<br>2) If machine has a governor, it may need adjustment | 3. Oil leak in pressure lines                |
| _____d. 1) Check reservoir and add oil if necessary<br>2) Check system for leaks that could cause loss of oil       | 4. Relief valves not properly set or leaking |
| _____e. 1) Back out orifice and adjust it<br>2) Check machine specifications for proper setting                     | 5. Oil viscosity too heavy                   |
| _____f. Check suction side of the system for leaks  | 6. Valve or regulators plugged               |

## TEST

- |  |   |  |
|--|---|--|
| <p>_____g.</p> <p>_____h.</p> <p>_____i.</p> <p>_____j.</p> <p>_____k.</p> <p>_____l.</p> <p>_____m.</p> | <p>1) Repair or replace pump</p> <p>2) Check for problems causing pump wear such as misalignment or contaminated oil</p> <p>1) Suction line could be dirty or have inner walls that are collapsing to cut off oil supply</p> <p>2) Clean or replace suction line</p> <p>3) Examine filter for plugging</p> <p>1) Test relief valves to make sure they are opening at their rated pressure</p> <p>2) Examine valves for damaged seats that could leak</p> <p>1) Examine and test valves, motors, cylinders, etc. for external and internal leaks</p> <p>2) If wear is abnormal, try to locate the cause</p> <p>1) Clean dirt from components</p> <p>2) Clean orifices</p> <p>3) Check source of dirt and correct</p> <p>1) Tighten fittings or replace defective lines</p> <p>2) Examine mating surfaces on couplers for irregularities</p> <p>Refer to machine technical manual for proper adjustment of components</p> | <p>7. Adjustable orifice restricted too much</p> <p>8. Badly worn pump</p> <p>9. Cold oil</p> <p>10. Components not properly adjusted</p> <p>11. Insufficient engine speed</p> <p>12. Restriction in suction line or filter</p> <p>13. Badly worn components</p> |
|--|---|--|

7. Discuss two problems and remedies for systems that operate too fast.

- a. \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- b. \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

## TEST

8. Match problems with remedies for systems that overheat.

- |         |  |   |
|---------|--|---|
| _____a. | Return control lever to neutral position when not in use                         | 1. Dirty oil  |
| _____b. | 1) Use oil recommended by manufacturer<br>2) Be sure oil viscosity is correct    | 2. Oil cooler malfunctioning  |
| _____c. | 1) Fill reservoir<br>2) Look for leaks   | 3. Incorrect relief valve pressure  |
| _____d. | 1) Drain and refill with clean oil<br>2) Look for source of contamination        | 4. Heat not radiating properly  |
| _____e. | Reset governor or reduce throttle  | 5. Restriction in pump suction line   |
| _____f. | Check pressure and clean or replace relief valves                                | 6. Operator holds control valves in power position too long, causing relief valve to open |
| _____g. | Examine and test valves, cylinders, motors, etc. for external and internal leaks | 7. Dented, obstructed, or undersized oil lines  |
| _____h. | Clean or replace   | 8. Low oil level  |
| _____i. | 1) Replace defective or undersized oil lines<br>2) Remove obstructions           | 9. Automatic unloading control inoperative  |
| _____j. | Clean or repair  | 10. Engine running too fast   |
| _____k. | Free all spools so that they return to neutral position                          | 11. Internal component oil leakage  |
| _____l. | Clean dirt and mud from reservoir, oil lines, coolers, and other components      | 12. Control valve stuck in partially or full open   |
| _____m. | Repair valve   | 13. Using incorrect oil   |

9. List four problems and remedies for foaming fluid.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_

## TEST

10. Match the problems with remedies for excessive pump noise.

- |  |   |
|--|---|
| <p>_____a.    1) Fill reservoir<br/>              2) Check system for leaks</p> <p>_____b.    Change fluid to correct viscosity</p> <p>_____c.    Operate pump at recommended speed</p> <p>_____d.    Clean or replace line between reservoir and pump</p> <p>_____e.    1) Disassemble and inspect pump and lines<br/>              2) Clean hydraulic system<br/>              3) Determine cause of dirt</p> <p>_____f.    Remove breather cap, flush, and clean air vent</p> <p>_____g.    1) Tighten or replace suction line<br/>              2) Check system for leaks<br/>              3) Replace pump shaft seal</p> <p>_____h.    1) Replace worn parts or complete pump if parts are badly worn or scored<br/>              2) Determine cause of scoring</p> <p>_____i.    Clean screen to prevent cavitation in pump</p> <p>_____j.    1) Repair pump<br/>              2) Look for cause of damage like contamination or too much pressure</p> <p>_____k.    1) Repair binding parts<br/>              2) Clean parts and change fluid if necessary</p> | <p>1. Sludge and dirt in pump</p> <p>2. Worn or scored pump bearings or shafts</p> <p>3. Inlet screen plugged</p> <p>4. Sticking or binding parts</p> <p>5. Low fluid level</p> <p>6. Suction line plugged or pinched</p> <p>7. Pump speed too fast</p> <p>8. Reservoir air vent plugged</p> <p>9. Broken or damaged pump parts</p> <p>10. Fluid viscosity too high</p> <p>11. Air in fluid</p> |
|--|---|

11. List two problems and remedies for leaking pumps.

- a. \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- b. \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

## TEST

12. Match problems with remedies for load drop when the control valve is in the neutral position.

- |         |   |   |
|---------|---|---|
| _____a. | 1) Check for leaks<br>2) Tighten or replace lines<br>3) Examine mating surfaces on couplers for irregularities                              | 1. Oil leaking past cylinder packings or O-rings              |
| _____b. | 1) Replace worn parts<br>2) If wear is caused by contamination, clean hydraulic system and determine the source                             | 2. Oil leaking past control valve or relief valves            |
| _____c. | 1) Clean or replace valves<br>2) Wear may be caused by contamination<br>3) Clean system and determine source of contamination               | 3. Leaking or broken oil lines from control valve to cylinder |
| _____d. | 1) Check linkage for binding<br>2) Make sure valve is properly adjusted and has no broken or binding parts such as spools or detent springs | 4. Control lever not centering when released                  |

13. List two problems which can cause the control valve to stick or work hard.

- a. \_\_\_\_\_
- b. \_\_\_\_\_

14. Select problems which can cause a control valve to leak by placing an "X" in the appropriate blanks.

- \_\_\_\_\_a. Tie bolts too loose
- \_\_\_\_\_b. Worn or damaged O-rings
- \_\_\_\_\_c. Oil level too low
- \_\_\_\_\_d. Cracked reservoir
- \_\_\_\_\_e. Broken valve parts
- \_\_\_\_\_f. Excessive wear between a select-fit spool and valve

15. List three problems which can cause a cylinder to leak.

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_

## TEST

16. List two problems which can cause a cylinder to actually lower when a control valve is moved to slowly raise a cylinder.

a. \_\_\_\_\_

b. \_\_\_\_\_

17. Match problems with remedies for power steering malfunctions.

_____a.	1) Bleed system 2) Check for air leaks	1. Worn or damaged bearings
_____b.	1) Components may not be adjusted properly 2) Parts may be worn or broken 3) Check for cause of wear	2. Internal leakage in system 3. System not properly timed
_____c.	Time according to manufacturer's instruction	4. Insufficient pressure
_____d.	Check and replace bearings in steering components	5. Air in system
_____e.	1) Check pump and relief valves 2) Contamination could cause valves to leak or pump to wear 3) Restricted filters	

18. Match problems with remedies for brake malfunctions.

_____a.	1) Warm up fluid or change to one of lighter viscosity 2) Use proper oil or brake fluid	1. Accumulator not working 2. Contaminated oil
_____b.	1) Bleed brake system 2) Find out where air is coming from	3. Heavy oil or improper brake fluid
_____c.	Clean and repair system and check for cause of contamination	4. Brake pedal return restricted
_____d.	1) Clean dirt from moving parts 2) Check linkage for damage 3) Brake pistons may be leaking	5. Air in system
_____e.	1) Check accumulator precharge 2) If accumulator is defective, repair or replace it	

## TEST

(NOTE: If the following activities have not been accomplished prior to the test, ask your instructor when they should be completed.)

19. Demonstrate the ability to:
  - a. Test a hydraulic pump.
  - b. Locate a problem in a hydraulic system.
  - c. Test a relief valve.
  - d. Test a control valve.
  - e. Test an actuator.

## DIAGNOSIS AND TESTING UNIT XIV

### ANSWERS TO TEST

1.
  - a. The systematic diagnosis of hydraulic system malfunctions
  - b. A statement or conclusion concerning the nature or cause of a problem
  - c. A device which is capable of measuring hydraulic system pressure flow and temperature and also has a valve for imposing a load onto the system
  
2.
 

a.	3
b.	5
c.	6

d.	2
e.	7
f.	4

g.	1
----	---
  
3.
  - a. By-pass tester
  - b. In-line tester
  
4.
 

a.	7
b.	14
c.	4
d.	17
e.	10
f.	6

g.	11
h.	1
i.	15
j.	8
k.	2
l.	13

m.	3
n.	9
o.	5
p.	12
q.	16
  
5. Any one of the following under each problem:
  - a.
    - 1) Examine suction side of system for leaks
    - 2) Make sure oil level is correct
  - b.
    - 1) Viscosity of oil may be too high at start of warm-up period
    - 2) Allow oil to warm up to operating temperature before using hydraulic functions
  - c.
    - 1) Check for dirt or gummy deposits, and if dirt is caused by contamination, try to find the source
    - 2) Check for worn or bent parts
  - d. Check for broken or worn parts and determine cause of pump damage
  - e. Clean relief valves
  - f.
    - 1) Suction line could be dirty or have inner walls that are collapsing to cut off oil supply
    - 2) Clean or replace suction line
    - 3) Check filter line for restrictions
  - g. Repair or replace cylinder packing
  
6.
 

a.	9
b.	5
c.	11
d.	1
e.	7

f.	2
g.	8
h.	12
i.	4
j.	13

k.	6
l.	3
m.	10
  
7. Discussion should include any two of the following:
  - a. Adjustable orifice installed backward or not installed — Install orifice parts correctly and adjust
  - b. Obstruction or dirt under seat or orifice — Remove foreign material and readjust orifice
  - c. Pressure set too high — Readjust pressure to manufacturer's specifications



## ANSWERS TO TEST

8.   a.    6                   f.    3                   k.    12  
      b.   13               g.   11               l.    4  
      c.    8               h.    5               m.    9  
      d.    1               i.    7  
      e.   10               j.    2
9.   Any four of the following:  
      a.   Low fluid level — Fill reservoir and look for leaks  
      b.   Water in fluid — Drain and replace fluid  
      c.   Wrong kind of fluid being used — Use fluid recommended by manufacturer  
      d.   Air leak in line from reservoir to pump — Tighten or replace suction line  
      e.   Kink or dent or in fluid lines — Replace fluid lines  
      f.   Worn seal around pump shaft — Clean sealing area, replace seal, and check fluid for contamination or pump for misalignment
10.   a.    5               e.    1               i.    3  
      b.   10               f.    8               j.    9  
      c.    7               g.   11               k.    4  
      d.    6               h.    2
11.   a.    Damaged seal around the drive shaft — Tighten packing or replace seal  
      b.   Loose or broken pump parts — Tighten or replace parts
12.   a.    3               c.    4  
      b.    1               d.    4
13.   Any two of the following:  
      a.   Misalignment or seizing of control linkage  
      b.   Tie bolts too tight  
      c.   Valve broken or scored internally
14.   a, b, e, f
15.   Any three of the following:  
      a.   Damaged cylinder barrel  
      b.   Rod seal leaking  
      c.   Loose parts  
      d.   Piston rod damaged
16.   Any three of the following:  
      a.   Damaged check valve in lift circuit  
      b.   Leaking cylinder packing  
      c.   Leaking lines or fittings to cylinder  
      d.   Detent springs need adjustment
17.   a.    5               d.    1  
      b.    2               e.    4  
      c.    3
18.   a.    3               d.    4  
      b.    5               e.    4  
      c.    2
19.   Performance skills evaluated to the satisfaction of the instructor